Engineering
Library

OCT 31 1927

MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

A.S.M.E. Annual Meeting

December 5 to 8, 1927
New York, N. Y.

The coming Annual Meeting of The American Society of Mechanical Engineers will be an exceptionally worthwhile event, not only because of the score of sessions, but because of its committee meetings, its good fellowship, and its all-around inspirational value. The National Exposition of Power and Mechanical Engineering will be held simultaneously. Study the program and abstracts of papers in this issue and plan to attend.

NOVEMBER 1927

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Oxwelding has introduced sheet metal to the engineer★

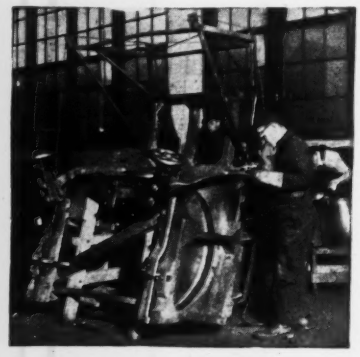
ENGINEERS well remember the day when sheet metal equipment was put together with riveted or locked-seam joints. They were either unsightly or flimsy.

Now it is a different story. With high test steel welding rods it is possible to make sheet metal joints that are stronger than the metal itself. This rigid, durable flush type of joint has found wide acceptance in many industries, not only because of its strength but because of its ability to take and hold a finish of baked enamel.

Modern iceless refrigerators, where permanently tight joints are essential, are possible because of the oxwelded joint. The construction of ventilating ducts has been greatly simplified by the flexibility of the oxwelding process. And their effectiveness is increased tremendously because oxwelded joints do not leak.

In the building of automobile bodies and aircraft fuselages, where strength and dependability are vital, are two modern applications of oxy-acetylene welding to sheet metal construction. The strength and finish of the oxwelded joint are more largely responsible than any single thing for the wider use of sheet metal in engineering construction.

Linde engineers have much valuable information on the use of the oxy-acetylene process in sheet metal construction. This information is available upon request.



THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation

UCC

General Offices: Carbide and Carbon Building
30 East 42d Street, New York
37 PLANTS . . . . . 105 WAREHOUSES

LINDE OXYGEN

★ No. 11 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 20th and Northampton Streets, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 49 | November, 1927 | Number 11

CONTENTS OF THIS ISSUE

Centenary Exhibition of the Baltimore & Ohio Railroad—"The Fair of the Iron Horse" ... 1169
The Characteristics of Modern Boilers ... *E. R. Fish* ... 1175
Application of Powdered Coal to Small Boilers of Industrial Plants ... *H. Kreisinger* ... 1177
Mechanical Equipment Used in Driving the Moffat Tunnel ... *D. W. Brunton* ... 1181
Quenching: A Practical Study on Rapid Cooling ... *P. J. Haler* ... 1187
Plant Location ... *T. S. Rogers* ... 1191
Shipbuilding in the United States ... 1195
Industrial Mobilization for National Defense ... *C. M. Schwab* ... 1200
Imagine Production Without Engineering ... *H. V. Coes* ... 1201
Machine Parts—Discussion ... 1203
The Effect of Atmospheric Smoke Pollution ... *A. S. Langsdorf* ... 1213
Organizing a Smoke-Abatement Campaign ... *Erle Ormsby* ... 1216
Comparison of Hydraulic Formulas and Theories—Discussion ... 1219
The Influence of Elasticity on Gear-Tooth Loads (Progress Report No. 7) ... 1228
Code on Instruments and Apparatus, Chapter 2, Part I—Barometers ... 1243
National Machine Tool Builders' Exposition at Cleveland ... 1257
A.S.M.E. Annual Meeting Program ... 1263
Synopses of Papers to Be Presented at A.S.M.E. Annual Meeting, December 5–8 ... 1265
Request Blank for Annual Meeting Papers ... 1272

DEPARTMENTAL

Survey of Engineering Progress ... 1232
Modern Conceptions Concerning Ignition and Combustion Processes in Diesel Engines; Short Abstracts of the Month
Engineering and Industrial Standardization ... 1248
Plumbing Equipment; Safety Code for Rubber Machinery; Wrought Iron and Steel Pipe and Tubing; Refrigeration Code; Electric Welding; etc.
The Conference Table ... 1250
Discussion of Questions on Railroads, Textiles, Wood Industries, etc.
Correspondence ... 1251
High-Temperature and High-Pressure Steam Lines; Needless Depreciation Charges
Work of A.S.M.E. Boiler Code Committee ... 1253
Editorial ... 1254
The "Metropolis;" The Schneider Cup Race; The Oil Situation in the United States; Gunning for Airplanes; The Divisions Advance; Frank C. Wight; The St. Louis Tornado; Commercial Standardization in the Department of Commerce; The Sixth Exposition of Power and Mechanical Engineering
Book Reviews and Library Notes ... 1260
The Engineering Index ... 1273

ADVERTISING

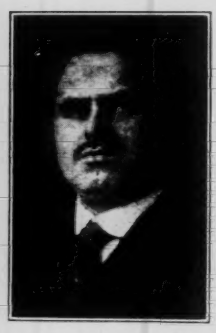
Display Advertisements ... 1
Professional Engineering Service Section ... 128
Classified List of Mechanical Equipment ... 133
Opportunity Advertisements ... 143
Alphabetical List of Advertisers ... 144

Price 60 Cents a Copy, $5.00 a year: to Members and Affiliates, 50 Cents a Copy, $4.00 a year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

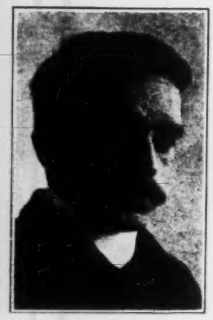
Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Copyrighted, 1927, by The American Society of Mechanical Engineers

ERLE ORMSBY



HENRY KREISINGER



P. J. HALER

E. R. FISH

H. V. COES

A. S. LANGSDORF

Contributors to This Issue

Charles M. Schwab's address before the cadets at West Point on Industrial Mobilization for National Defense is published in this issue. Mr. Schwab, president of the A.S.M.E. for the current year, is chairman of the Board of Directors of the Bethlehem Steel Corporation, as well as director in many other industrial and commercial enterprises.

* * * * *

H. V. Coes, president and general manager of the Belden Manufacturing Co., Chicago, was graduated from the Massachusetts Institute of Technology. He has been associated with the Searchlight Gas Co., Lockwood, Greene & Co., Sentinel Manufacturing Co., Gunn, Richards & Co., and Ford, Bacon & Davis. Mr. Coes assisted in the design, built, and operated the largest carbonic-acid plant in the world in Cambridge, Mass. He has reorganized munitions plants in Canada and the United States.

* * * * *

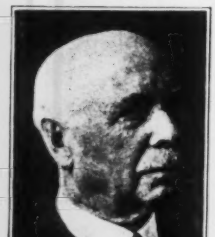
D. W. Brunton, Chairman of the Board of Consulting Engineers to the Moffat Tunnel Commission, holds the degree of Doctor of Science from the University of Colorado. He is a past-president of the American Institute of Mining and Metallurgical Engineers and also of The American Mining Congress. In 1898 he was awarded the Telford Premium by the Institution of Civil Engineers in England, and last February was awarded the Saunders gold medal by the A.I.M.E. for achievements in mining and tunneling. For the past fifty-two years he has been engaged in mining and tunneling.

* * * * *

E. R. Fish, vice-president of the Heine Boiler Co., St. Louis, Mo., received his M.E. from Washington University, St. Louis, in 1892. He became associated with his present concern in 1893 as assistant engineer, and has held his present position since 1919.

* * * * *

Henry Kreisinger, research engineer with the Combustion Engineering Corporation, New York, since 1920, is a graduate of the University of Illinois with the degrees of B.S. and M.E. From 1906 to 1910 Mr. Kreisinger worked with Professor Breckenridge of Yale University on fuel tests conducted by the U. S. Geological Survey. For



D. W. BRUNTON

C. M. SCHWAB

three years he was associated with the Clinchfield Fuel Co., and then for seven years was associated with the U. S. Bureau of Mines.

* * * * *

Percy J. Haler, principal of the Leyton Technical College, England, holds the degrees of B.Sc. and M.Sc. from Leeds University. He was trained with the firm of Greenwood & Batley, engineers, Leeds. From 1914 to 1918 he was associated with the London County Council as superintendent of precision and gage manufacture. He received the M.B.E. in 1920 and is the author of a number of textbooks.

* * * * *

T. S. Rogers has been for the past five years district manager of the New York office of the Ballinger Co., architects and engineers, and is now associated with C. Stanley Taylor, consultant. He served with the constructional division, Quartermaster Corps of the U. S. Army, in Washington, during 1917 and 1918 and in 1919 became post utilities officer and constructing quartermaster of Fort Bayard in New Mexico. For the next three years Mr. Rogers was associated with the Housing Co. of Boston.

* * * * *

A. S. Langsdorf, director of department of industrial engineering and research, Washington University, St. Louis, was graduated from that institution in 1898 with the degree of B.S., later receiving his M.E. from Cornell University. Dean Langsdorf was associated from 1898 to 1920 with Washington University, the last ten years of which he was dean of the schools of engineering and architecture. From 1920 to 1922 he was connected with the Crunden-Martin Manufacturing Co., and for the next three years served as vice-president and chief engineer of the Alvey Manufacturing Co.

* * * * *

Erle Ormsby is president and general manager of Donk Brothers Coal & Coke Co., St. Louis, Mo. Mr. Ormsby was formerly associated with the Merchants Ice & Coal Co., also of St. Louis, as vice-president and general manager. He served as president, in 1925, of the National Association of Practical Engineers.

A.S.M.E Annual Meeting

New York, N. Y., December 5-8, 1927

The tentative program of the Forty-eighth A.S.M.E. Annual Meeting, published in this issue, reveals a wealth of valuable technical material. The excellence of this program attests anew the service that A.S.M.E. meetings are rendering as great clearing houses of information and inspiration.

The Henry Robinson Towne Lecture will be given on Thursday evening, December 8, by Prof. T. S. Adams, professor of economics at Yale University, and president of the American Economic Association, who will speak on the Relationship Between Industry and Taxation.

All of the emphasis is not on the technical sessions for many committees are busily engaged in arranging for the entertainments and excursions that will form an important part of the program.

See the current issues of the A.S.M.E. NEWS for details of the non-technical events.

MECHANICAL ENGINEERING

Volume 49 November, 1927 No. 11

Centenary Exhibition of the Baltimore & Ohio Railroad—"The Fair of the Iron Horse"

IT WAS pointed out in an editorial published in the April, 1927, issue of MECHANICAL ENGINEERING that America has reached what may be called the Centennial Period of railways. Among the great systems the Delaware & Hudson marked the end of its first hundred years of corporate existence in 1923, the New York Central did likewise in April, 1926, and now has come the centennial of the Baltimore & Ohio.

In true southern manner the Baltimore & Ohio has held a big party upon its hundredth birthday, thereby presenting an unusual opportunity of getting a real insight into the family history and intimate daily life of a venerable and important American transportation system.

The hundredth birthday of the Baltimore & Ohio was celebrated by means of the "Fair of the Iron Horse." This event, as the name implies, was based upon the idea of the old-fashioned horse fair and followed this plan very closely in the layout of the fairgrounds, the familiar oval track, and other details. The only real difference was that the principal actors—the horses—were of iron and consumed wood or coal instead of hay and oats.

Before going into further details of the fair itself and the individual exhibits therein, something should be said of the history of the company behind it. Unlike certain other of the older American railroads, the Baltimore & Ohio did not come into being as a canal project but rather in competition with a canal project. The immediate success of the Erie Canal opened the eyes of the business men of Baltimore to the growing importance of traffic with the western country as a determining factor in the growth and importance of cities on the eastern seaboard.

They realized that if Baltimore was to continue to be commercially important, it must in some way tap the great reservoir of commerce which lay beyond the Alleghany Mountains. As the mountain barrier precluded the possibility of a canal, they decided to trust their fortunes in what was then a very questionable experiment—the railroad. Although steam locomotives were just then beyond the range of their imagination and they proposed to use horses on the level stretches supplemented by cable engines on the heavy grades, they did nevertheless vision the Ohio River, 300 miles away, as their goal. In those days of river transportation a rail terminus upon the Ohio River meant close contact with all that counted in interior America.

After this decision quick action was taken. The charter was obtained from the State of Maryland on February 28, 1827, and the Baltimore & Ohio Railroad Company was incorporated on April 24. The capital stock was rapidly subscribed, and actual surveys for the railroad west of Baltimore were begun by United States Army engineers that same summer.

The construction work was formally begun on July 4, 1828, when the "First Stone" was laid in a field near the residence of James Carroll at what was then the westerly limit of the city of Baltimore. This ceremony was conducted by the Baltimore Masonic Lodges, assisted by the venerable Charles Carroll of Carrollton, at that time the last surviving signer of the Declaration of Independence.

By the beginning of the year 1830 a double-tracked line was completed from Baltimore to Ellicott's Mills, 14 miles to the west, and on the 24th of May, horse-drawn cars began to run upon regular schedules. The immediate success of this spurred the builders to renewed activities on the drive toward the west, but at the same time made the Ohio River seem a long distance away when thought of in terms of horse-drawn cars.

The inadequacy of this motive power was particularly evident to Peter Cooper, of New York, whose land investments in Baltimore caused him to take a lively interest in whatever was likely to affect the future of the city. Peter Cooper was rich and influential, and

FIG. 1 THE ORIGINAL "ATLANTIC" OF 1832, THIRD LOCOMOTIVE OF THE BALTIMORE & OHIO RAILROAD, WITH ITS TRAIN OF "IMLAY" COACHES

at the same time highly mechanical. First he undertook to get the directors of the railroad company to experiment with steam locomotives on their own account. Failing in this he undertook to prove to them by his own experiments that steam was the power they should use. To do this he designed and built in New York and erected in 1829 at Mount Clare, in the suburbs of Baltimore, his locomotive, the *Tom Thumb*. After much work he succeeded in the spring of 1830 in getting this little locomotive to work well enough to convert the directors to the steam idea. There followed in the summer of 1831 a competitive test in which three locomotives

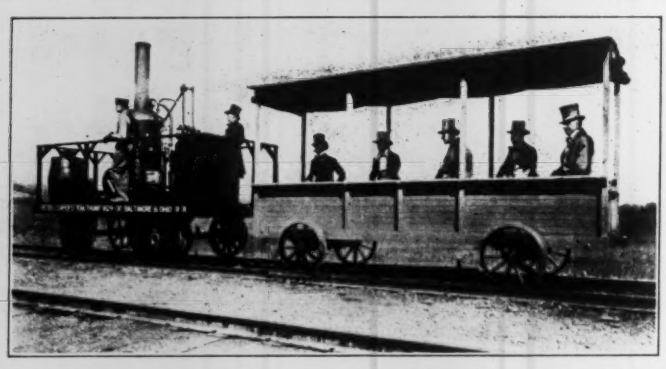


FIG. 2 REPRODUCTION OF PETER COOPER'S LOCOMOTIVE "TOM THUMB," OF 1830, WITH ITS PASSENGER CAR, AS USED IN THE FIRST SUCCESSFUL DEMONSTRATION OF STEAM POWER ON THE BALTIMORE & OHIO

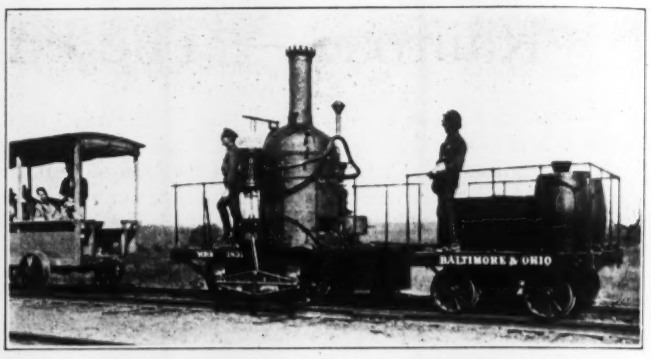


FIG. 3 REPRODUCTION OF PHINEAS DAVIS' "YORK" OF 1831, THE FIRST LOCOMOTIVE TO BE PUT IN REGULAR SERVICE ON THE BALTIMORE & OHIO RAILROAD

were entered. Of these the *York*, built at York, Pa., by Phineas Davis, was an outstanding success and was put into immediate service, Davis himself being appointed chief mechanical engineer of the railroad. In this capacity he was one of the founders of the extensive B. & O. locomotive and car shops at Mount Clare. Both the *Tom Thumb* and the *York* had vertical boilers, and this peculiar type of locomotive persisted on the Baltimore & Ohio until 1837. More detailed information about the locomotives will be given later.

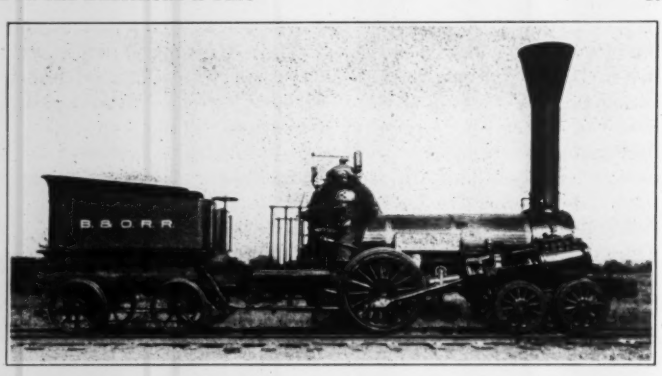


FIG. 4 THE "WILLIAM GALLOWAY," REPLICA OF THE "LAFAYETTE" OF 1837, WHICH WAS THE FIRST LOCOMOTIVE WITH HORIZONTAL BOILER USED ON THE BALTIMORE & OHIO

The westward progress of the railroad construction continued constantly but at an irregular rate. In 1832 it was at Frederick, sixty miles from Baltimore. On December 1, 1834, it reached a point on the Potomac opposite Harpers Ferry. There followed a period of financial panics and it was not until November 5, 1842, that the line reached Cumberland. After what were at that time very difficult feats of grading, tunneling, and bridge building in the Alleghanies the "main stem" of the Baltimore & Ohio finally reached its objective, the Ohio River, at Wheeling on January 1, 1853.

As one of the key railroads in the defense of the Union the Baltimore & Ohio was under constant attack during the Civil War and suffered enormous losses. Through the vigorous efforts of John W. Garrett, who served as its president for twenty-six years, the railway survived this critical period, and after the war continued its rapid growth toward its present status as one of the great railway systems of the United States.

Getting back again to the subject of the Centenary Exhibition, it should be explained that the central feature was a daily moving pageant. This was primarily one of locomotives, from the earliest down to the very latest. These locomotives, one by one in the order of their age, came slowly down the track in front of the grandstand under their own steam, and later lined up for inspection. They were preceded by examples of earlier forms of transportation such as Indian "travois" and Red River carts, post chaises, stage coaches, "covered wagons," etc. and were interspersed with elaborate historical floats. The whole pageant, with its stirring band music arranged for the occasion, was most impressive—something which will not be equaled in many a long day.

The other main division of the exhibition—which may be called the static part—was almost equally remarkable. This was housed in three specially constructed buildings of brick and steel, namely, the Hall of Transportation, 502 feet long by 60 feet wide, the Traffic Building, and the Allied Services Building.

On two tracks the entire length of the Hall of Transportation were thirty-one full-size wooden models of steam-driven locomotives from the time of Sir Isaac Newton, including the steam wagon built and operated by Nicholas Cugnot in France in 1769. These models were painted to look exactly like the originals. There were also in this building a remarkable collection of railway and locomotive pictures, panoramas, bridge models, and displays of such accessories such as braking systems, mechanical stokers, switches and signals, and railway timepieces. Just outside this building were shown full-size sections of complete track construction featuring rails from the early iron strap rails laid on wood stringers mortised into sleepers, down to the present-day 130-lb. steel T-rail laid on creosoted cross-ties set in crushed-rock ballast.

The Traffic Building was given over to the coöperative activities of modern railroads, including the promotion of industrial development, the development of geological resources, the encouragement of scientific farming methods, and the promotion of such movements as that of "Safety First." The Allied Services Building was devoted to complete displays of the development and modern applications of the telegraph, the telephone, railway express, and mail services, and exhibits by the large steamship companies.

While it was almost impossible to find a single one of the vast number of exhibits which was not of direct interest to mechanical engineers, space here demands that selection be made and so the "Iron Horses" themselves have been singled out for more or less detailed description.

Leading the procession of self-propelled vehicles in the pageant was a carefully constructed replica of Peter Cooper's *Tom Thumb*, shown in Fig. 2. This four-wheeled machine weighs less than a ton and has a vertical boiler with a long-stroke vertical single-cylinder engine behind the boiler driving the rear set of wheels through gears. Draft is developed by a fan blower set in front of the boiler and belted to a pulley on the front axle. The original *Tom Thumb* made its first successful trip on August 25, 1830, from Baltimore to Ellicott's Mills and return, a distance of twenty-six miles for the round trip. It pushed an open car carrying eighteen passengers, making the outgoing trip in an hour and a quarter and the return trip in fifty-seven minutes. Peter Cooper, who thus became the father of steam transportation on the Baltimore & Ohio, was elected an Honorary Member of The American Society of Mechanical Engineers in 1882, when he was in his ninetieth year.

Of the five vertical-boiler locomotives which followed the *Tom*

Thumb the first—Phineas Davis' *York*—was shown in the pageant by a replica, a cut of which appears herewith as Fig. 3. The *York* had two cylinders, one on each side of the vertical boiler, these being connected by rods to trussed side rods cranked to both sets of wheels. The *York* had four wheels and weighed $3\frac{1}{2}$ tons.

The *Atlantic* was also built by Phineas Davis at York, Pa., and was conveyed to Baltimore by ox carts in 1832. The original engine appeared in the pageant and is shown in Fig. 1. It is a rather formidable looking machine of the "grasshopper" type, so called because of the long connecting rods at the front of the boiler resembling in appearance and in action the hind legs of this insect. The two vertical cylinders operate walking beams to the outer ends of which are coupled the connecting rods. At their lower ends the connecting rods are cranked to a large spur gear which meshes with a smaller one on the front axle as before described. The *Atlantic* has four wheels, weighs $6\frac{1}{2}$ tons, and originally carried a steam pressure of 50 lb.

The first appearance of the horizontal-boiler type of locomotive upon the Baltimore & Ohio was that of the *Lafayette*, built in 1837 by William Norris & Company. A replica of the *Lafayette*, called the *William Galloway*, appeared in the pageant under steam and is shown in Fig. 4. Quaint as it is to us of today, it had nevertheless the distinct rudiments of the modern locomotive. The *Lafayette* succeeded beyond the expectations of its designer, especially in grade-climbing ability, and set the precedent of this new type of engine.

The first locomotive builder in America who succeeded in combining beauty with utility in his productions was William Mason, of Taunton, Mass. This was demonstrated in the pageant as the original B. & O. *William Mason No. 25* steamed down the track. This handsome locomotive, which is shown in Fig. 5, was built in 1856 and was one of the finest passenger engines of its time. It weighs 28 tons, has link-motion valve gear, and the horizontal cylinders are bolted to a cast-iron saddle fitted under the round smokebox. The wagon-top boiler is 46 in. in diameter at the smokebox and the cylinders are 15 × 22 in. It has a four-wheel leading truck, and two pairs of drivers which are 60 in. in diameter.

Another original locomotive of a slightly later period which appeared in the pageant was the *William Crooks*, shown in Fig. 6. This was built in 1861 by Smith & Jackson, of Paterson, N. J., and was the first locomotive to pull a train west of the Mississippi. On June 28, 1862, this locomotive drew the first passenger train from St. Paul to St. Anthony, now Minneapolis, a distance of ten miles. The *William Crooks* has a weight of 36,000 lb. on the drivers, carries 120 lb. steam pressure, and has a tractive of 5000 lb. It was originally a wood burner, the tender holding 2 cords of wood and 2500 gallons of water, but when wood became scarce in Minnesota it was converted to coal. It has 12 × 22-in. cylinders and 63-in. drive wheels. This engine was named after William Crooks, the first chief engineer of the St. Paul & Pacific Railroad. This was the beginning of the present Great Northern Railway, which sent this historic engine

FIG. 5 THE "WILLIAM MASON," BUILT AT TAUNTON, MASS., IN 1856 BY WILLIAM MASON, "THE FATHER OF THE AMERICAN TYPE OF LOCOMOTIVE." ENGINE WEIGHED 28 TONS AND WAS THE FIRST ONE TO HAVE LINK-MOTION VALVE GEAR

FIG. 6 THE "WILLIAM CROOKS," BUILT IN 1861 AT THE NEW JERSEY LOCOMOTIVE & MACHINE WORKS, PATERSON, N. J., BY SMITH AND JACKSON, FOR THE ST. PAUL & PACIFIC, NOW PART OF THE GREAT NORTHERN. PULLED THE FIRST TRAIN WEST OF THE MISSISSIPPI

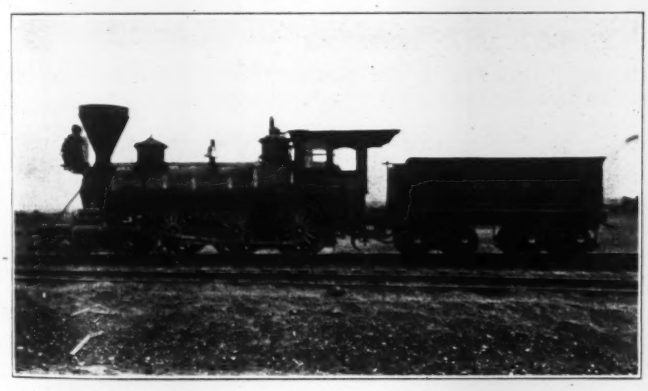


FIG. 7 THE "THATCHER PERKINS," BUILT IN 1863 AT THE MOUNT CLARE SHOPS OF THE BALTIMORE & OHIO FOR PASSENGER SERVICE ON HEAVY GRADES IN THE ALLEGHANIES

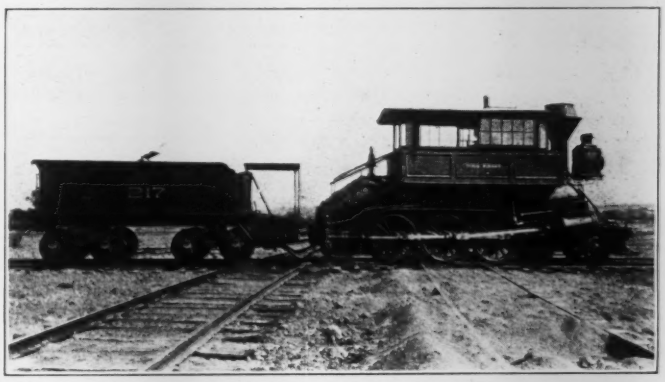


FIG. 8 THE ROSS WINANS "CAMELBACK," BUILT AT THE MOUNT CLARE SHOPS IN 1869 AND ONE OF THE MOST POWERFUL FREIGHT LOCOMOTIVES OF ITS TIME

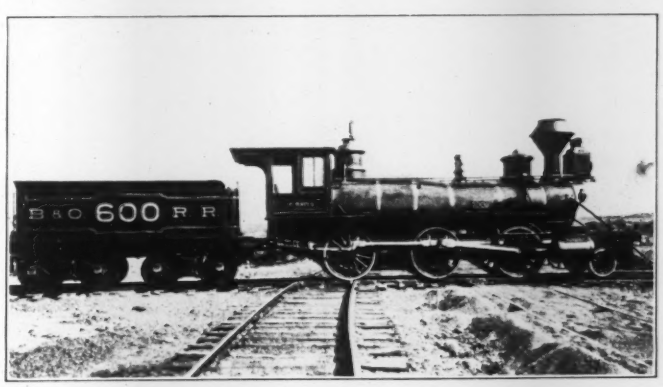


FIG. 9 THE "J. C. DAVIS," BUILT IN 1875 AT THE MOUNT CLARE SHOPS FOR HEAVY PASSENGER SERVICE IN THE MOUNTAINS AND AT THAT TIME THE HEAVIEST PASSENGER ENGINE IN EXISTENCE

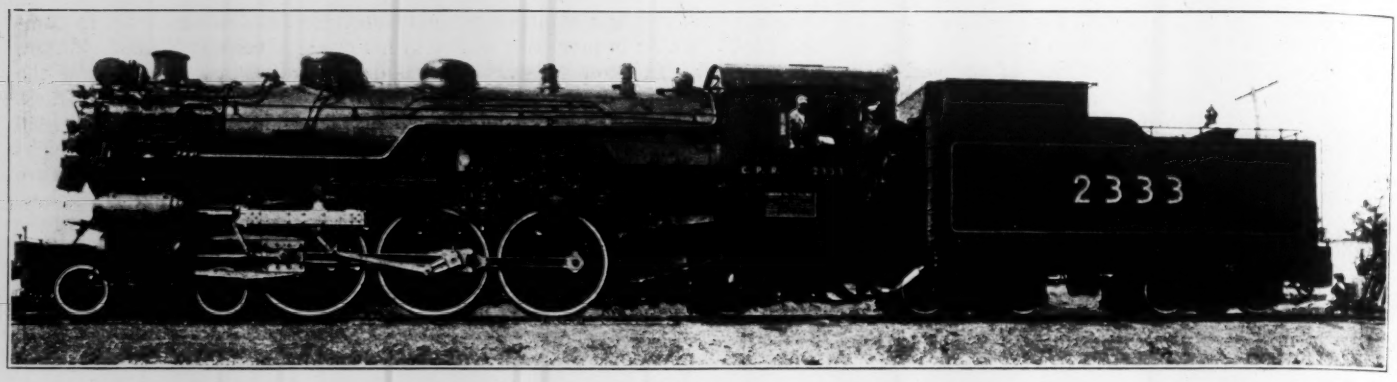


FIG. 10 CANADIAN PACIFIC LOCOMOTIVE NO. 2333 OF THE PACIFIC 4–6–2 TYPE, BUILT IN 1926 AT THE MONTREAL SHOPS AND THE MOST POWERFUL LOCOMOTIVE YET CONSTRUCTED FOR THE CANADIAN PACIFIC LINES

FIG. 11 "CONFEDERATION NO 6100," BUILT IN 1927 AT THE KINGSTON SHOPS OF THE CANADIAN NATIONAL RAILWAY. IS OF THE 4–8–4 TYPE, WITH BOOSTER. DESIGNED FOR STRENUOUS PASSENGER SERVICE. LARGEST LOCOMOTIVE IN THE BRITISH EMPIRE

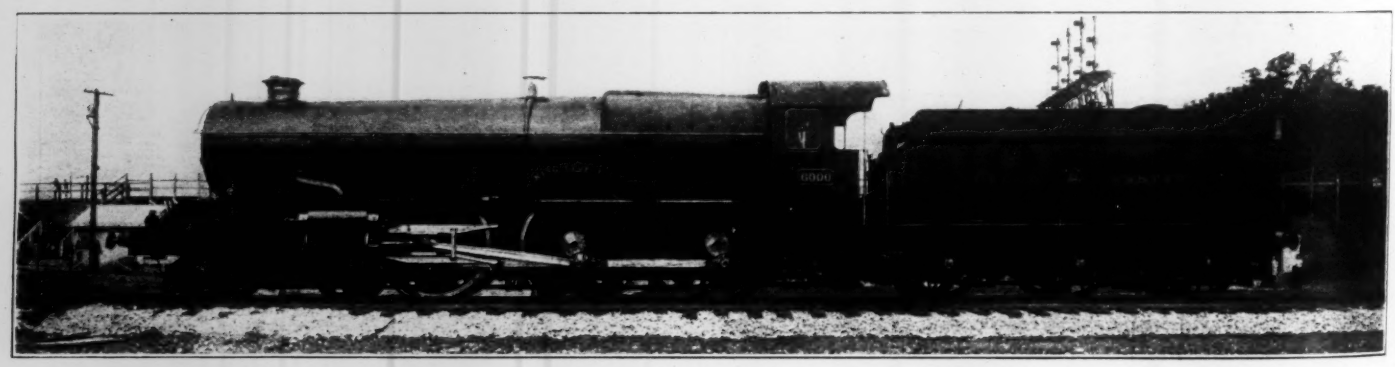


FIG. 12 THE "KING GEORGE V" OF THE GREAT WESTERN RAILWAY OF ENGLAND, BUILT AT THE SWINDON WORKS IN 1927. A 4-CYLINDER 4-6-0 TYPE AND THE MOST POWERFUL EXPRESS LOCOMOTIVE OF GREAT BRITAIN

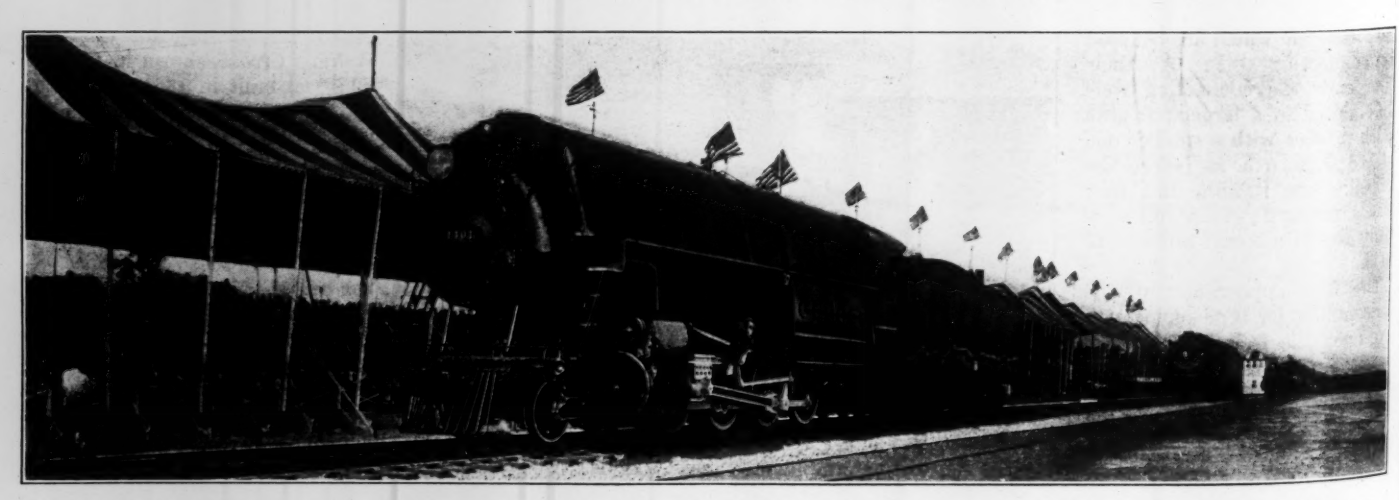


FIG. 13 THE "JOHN B. JERVIS" OF THE DELAWARE & HUDSON RAILROAD. 2–8–0 CROSS-COMPOUND CONSOLIDATION-TYPE FREIGHT LOCOMOTIVE, BUILT IN 1927 BY THE AMERICAN LOCOMOTIVE COMPANY AT SCHENECTADY. WATER-TUBE FIREBOX BOILER CARRYING 400 LB. PRESSURE

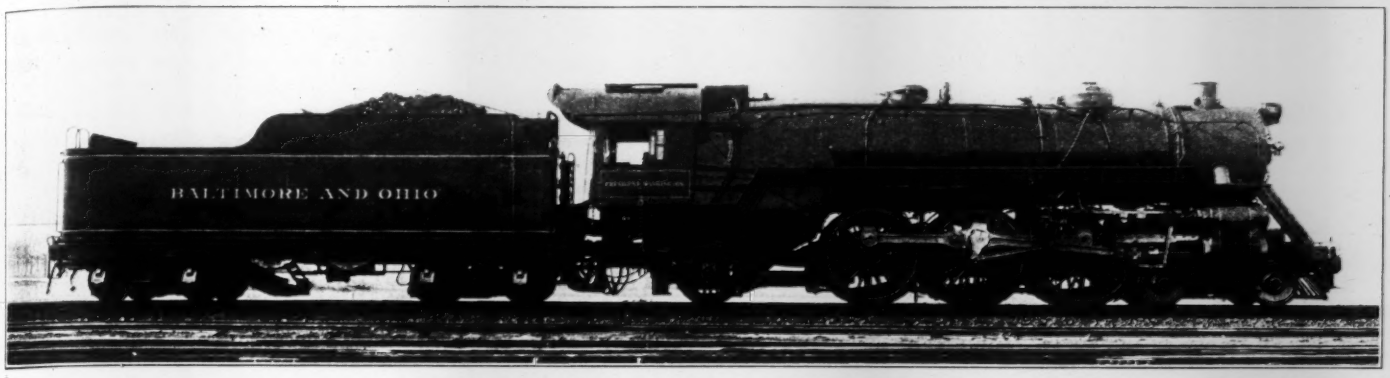


FIG. 14 THE "PRESIDENT WASHINGTON," BUILT IN 1927 BY THE BALDWIN LOCOMOTIVE WORKS FOR THE BALTIMORE & OHIO. HIGH-SPEED PASSENGER LOCOMOTIVE OF THE 4-6-2 PACIFIC TYPE FOR NEW YORK–WASHINGTON SERVICE

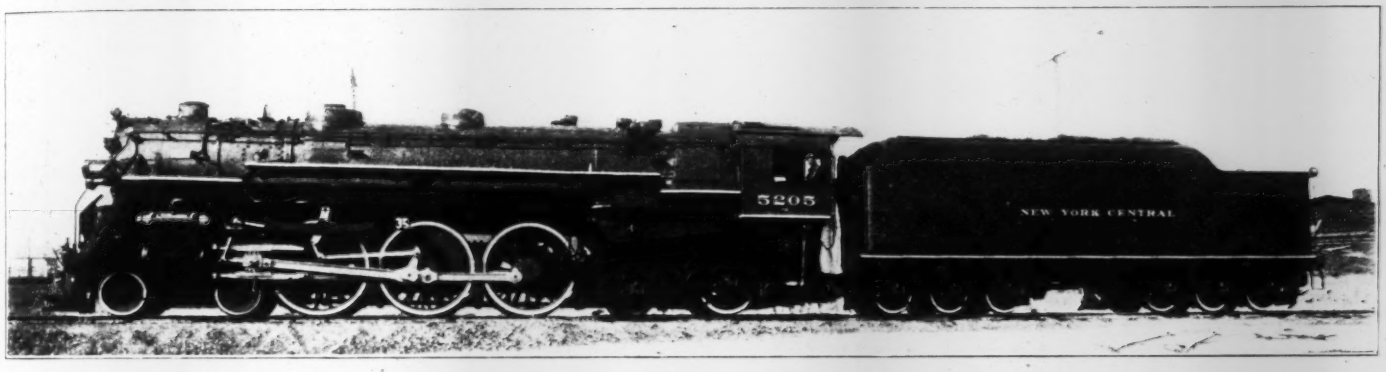


FIG. 15 HUDSON-TYPE LOCOMOTIVE OF THE NEW YORK CENTRAL LINES. BUILT IN 1927 FOR SERVICE ON THE TWENTIETH CENTURY LIMITED. A 4-6-4 TYPE DEVELOPING A MAXIMUM OF 4073 CYLINDER HP.

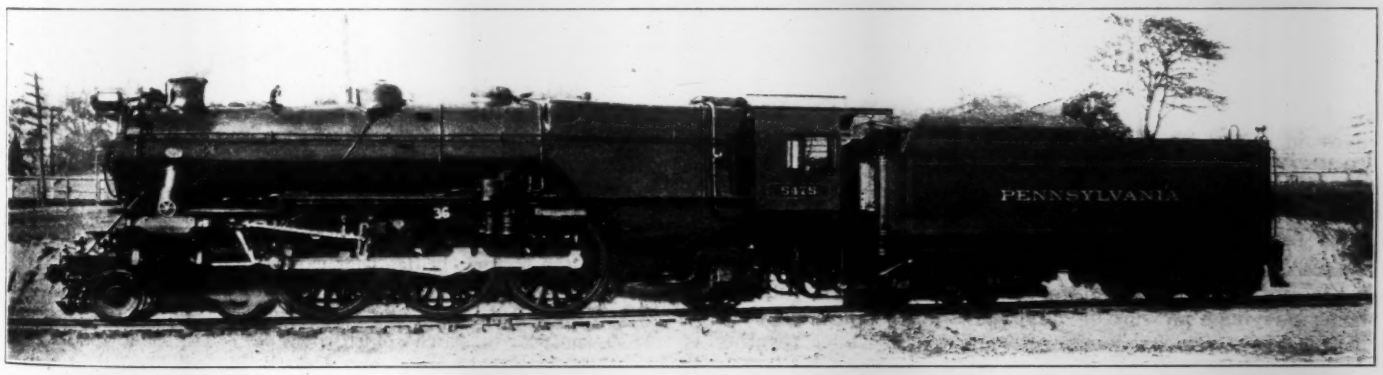


FIG. 16 LOCOMOTIVE NO. 5475 OF THE PENNSYLVANIA RAILROAD, BUILT IN 1926. A PASSENGER LOCOMOTIVE OF THE 4-6-2 TYPE WITH A TRACTIVE EFFORT OF 44,146 LB.

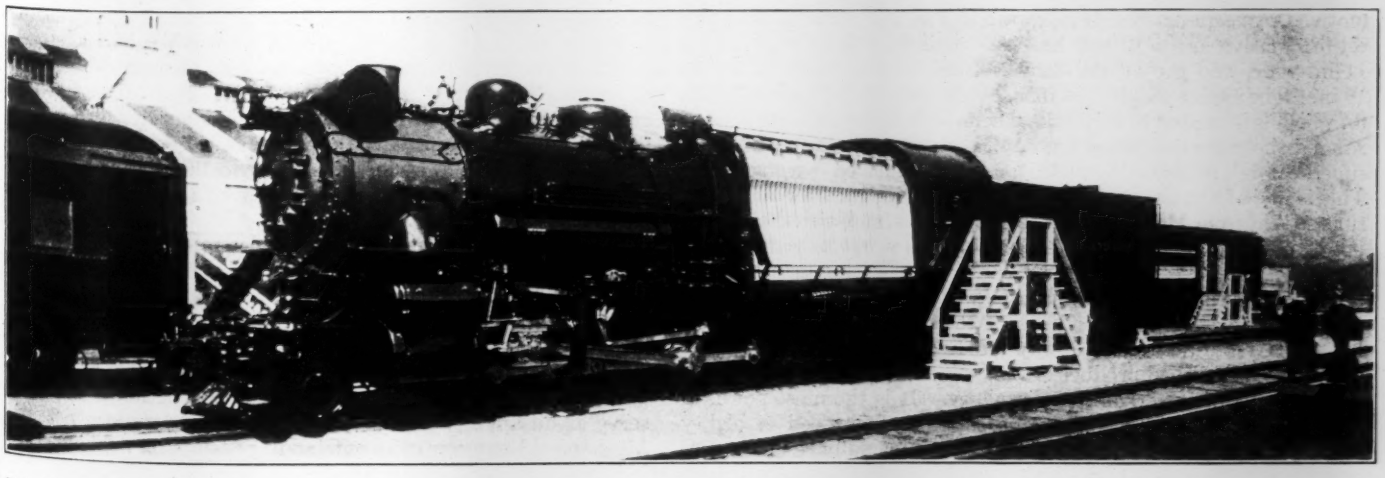


FIG. 17 BALTIMORE & OHIO LOCOMOTIVE NO. 4045, BUILT IN 1927. TENDER EQUIPPED WITH AUXILIARY ENGINE. STRIPPED TO SHOW DETAILS OF WATER-TUBE FIREBOX BOILER

with its train to the Exhibition to exemplify developments of its era.

An example of what was considered an extraordinarily powerful locomotive in 1863 was given in the original *Thatcher Perkins*, shown in Fig. 7. This ten-wheeler was built at the Mount Clare shops to haul passenger trains over the 17-mile grade (116 ft. to the mile) in the Alleghany Mountains between Piedmont and Grafton. It was the principal locomotive in this service up to 1890, with the exception of a period during the Civil War when it was captured and carried south by the Confederate Army. Some of the specifications of this engine are: extended wagon-top boiler 474¼ in. in diameter with combustion chamber ahead of firebox separated by water bridge wall, carrying 130 lb. steam pressure; firebox 34 × 84 in.; grate area 19.8 sq. ft.; 138 tubes 2¼ in. by 12 ft. 4 in.; total heating surface 1112.7 sq. ft.; cylinders 19 × 26 in., with Gooch or stationary link valve gear; drivers 60 in.; total weight 90,700 lb., at first considered too heavy for the track.

Another B. & O. original fully as distinctive as the first vertical-boiler engines was the Ross Winans *Camelback* of 1869. This is shown in Fig. 8. This engine No. 217 was one of a number of heavy freight locomotives designed by Ross Winans and utilizing his peculiar type of boiler with overhanging sloping-top firebox and with large dome at forward end. The engineer's cab was placed on the top of the boiler, like a camel's hump, to keep down the overall length of the engine and to give better vision and ventilation. No. 217 is a ten-wheeler with 50-in. drivers, has 19 × 22-in. drivers, has a total weight of 77,000 lb. and with 115 lb. boiler pressure exerted a tractive effort of 14,850 lb.

Of the period of 1875 there was present the original *J. C. Davis*, No. 600, shown in Fig. 9. This was the first passenger locomotive of the Mogul type used by the Baltimore & Ohio and was built by master of machinery J. C. Davis at the Mount Clare shops for the mountain service. This engine has a boiler 48¾ in. in diameter, cylinders 19 × 26 in., and at 110 lb. boiler pressure exerted a tractive effort of 14,700 lb. The weight complete is 90,400 lb., 76,550 lb. being on the drivers and at the Centennial in Philadelphia in 1876 it received the gold medal as the heaviest passenger engine in existence.

It will be necessary here on account of space limitations to pass by many other intensely interesting examples of old-time locomotives in the pageant, including New York Central's famous *De Witt Clinton*. It will likewise be necessary to pick only a few of the many outstanding modern designs and to describe these very briefly.

Of the modern engines taking part in the pageant Fig. 10 shows No. 2333 of the Canadian Pacific Railway, one of their latest passenger locomotives operating out of Montreal. This has a nickel-steel boiler carrying a pressure of 250 lb. per sq. in. The drivers are 75 in. in diameter. The weight of engine and tender together is 497,000 lb., the tractive effort 45,000 lb. and the locomotive is capable of hauling twelve steel coaches at a speed of 80 miles an hour.

Another visitor from Canada was the Canadian National locomotive *Confederation* No. 6100, shown in Fig. 11. This is the largest locomotive in the British Empire. It is 15 ft. 4 in. high, 10 ft. 11 in. wide, and the overall length of engine and tender is 93 ft. 10 in. The engine weighs 326 tons, exerts a tractive effort of 56,800 lb. which is increased to 69,700 lb. when the booster goes into action. Among the refinements are mechanical stokers, feedwater heaters, superheaters, multiple throttles and power-driven reverse gear. This is one of a lot of fifty such locomotives designed for such long runs as that from Montreal to Sarnia, 511 miles, and with the reserve power of the booster capable of meeting the worst blizzard conditions.

A very unusual sight to Americans was a visitor from overseas—the locomotive *King George V*—sent to the Centenary Exhibition by the Great Western Railway of England. This beautifully designed and finished product of the Swindon Works is at the same time capable of remarkable performance. It is the most powerful type of English locomotive and is capable of a speed of eighty miles per hour. It has four cylinders, two inside ones being connected to the forward pair of drivers and the two outside ones connected to the second pair, the drivers being 78 in. in diameter. The boiler is of the high-pressure superheater type, with a copper firebox, and carries 250 lb. pressure. The weight of the engine alone is 89 tons and the tractive effort 40,300 lb. It has a Walschaerts valve gear and is fitted with a vacuum braking system. It is bright green in color, with polished copper and brass trim.

The Delaware & Hudson Railroad sent something ultra-modern to the Exhibition in their locomotive *John B. Jervis*, shown in Fig. 13. This remarkable giant of the rails is a consolidation-type freight locomotive with a water-tube firebox boiler carrying 400 lb. pressure. The total weight of engine and tender is 639,500 lb. The tractive effort when operating simple is 84,300 lb., compound 70,300 lb., and with the booster in operation is 88,300 lb. The steam dome, smokestack, whistle, bell, etc. are sunk to the level of the top to the engine.

As an example of the latest type of Baltimore & Ohio high-speed locomotives the *President Washington*, shown in Fig. 14, appeared in the pageant, drawing a section of the Capitol Limited. This is a 1927 product of the Baldwin Locomotive Works and is of the Pacific type. It carries 230 lb. boiler pressure, has 27 × 28-in. cylinders, weighs with tender 270 tons, and exerts a tractive effort of 50,000 lb. Among the accessories are a superheater, power reverse gear, stoker, and automatic train control.

The New York Central contributed to the pageant one of their latest Hudson-type locomotives—No. 5205. This 308-ton locomotive, one of those used to haul the 20th Century Limited, is shown in Fig. 15. This engine develops 4073 cylinder horsepower at 66 miles an hour. All gages are mounted upon an instrument board in the most convenient line of vision, and all levers and valves are assembled within easy reach of the engineman as he sits in a comfortable position. The throttle is an easy-working multiple-disk affair, and reverse gear, cylinder cocks, sander, bell, and whistle are all operated by compressed air.

The modern representative of the Pennsylvania Railroad in the pageant was their new passenger locomotive No. 5475, shown in Fig. 16. This weighs complete 308,890 lb., carries steam at 205 lb. pressure and exerts a tractive effort of 44,146 lb. The cylinders are 27 × 28 in. and the engine has 80-in. drivers.

Among the interesting "static" exhibits was the Baltimore & Ohio locomotive No. 4045, shown in Fig. 17. This 1927 railway mechanical engineering development has a water-tube firebox which, as the cut illustrates, was shown stripped of its external sheathing to reveal the tube arrangement. The cut also shows the system of stairways by which visitors were enabled to comfortably inspect the locomotive cabs.

Another particularly interesting exhibit was a scenic model, 60 ft. long, 12 ft. deep and 8 ft. high, of Harpers Ferry. This model showed the historic bridge that carried both the Baltimore & Ohio trains and the highway over the Potomac River and the adjoining Chesapeake and Ohio Canal. The time chosen for this model was 1859, the year in which John Brown of Ossawatomie conducted his epoch-making raid upon the United States Arsenal at Harpers Ferry. The engine house, which became known as John Brown's Fort, could be recognized.

The chief feature of this model, however, was the combined bridge of the railroad and the highway. The railroad through this bridge, with its sharp curves at both approaches, was long recognized by engineers as one of the most difficult and dramatic bits of railroad location in the world. The bridge, itself, some 700 ft. in length, to the average man, was more distinguished by the curious fact that in its center it held a complete railroad junction, the main line of the B. & O. swerving off sharply to the right, while the line of the branch railroad to Winchester, Va., continued straight ahead.

It would require many volumes to adequately describe the Baltimore & Ohio Centenary Exhibition in its many phases—historical, mechanical, etc. In fact, the official catalog devoted only to brief notes on each exhibit developed into a book of 172 pages. In this article we can therefore only hope to give a conception of the vast amount of careful planning and effective carrying out of these plans involved in the project. Beyond this we hope that it may serve as an appreciation on the part of The American Society of Mechanical Engineers of an outstanding example of public education in the history and present status of one of the most important branches of engineering—that concerned with railways and their operation.

The Characteristics of Modern Boilers

By E. R. FISH,[1] ST. LOUIS, MO.

THE successful introduction of the steam turbine and its tremendously rapid growth in use and size of units have resulted in making it the one piece of modern power-plant machinery responsible for the great changes that have come about in boiler-room equipment. The relatively small space occupied by the steam turbine per unit of power has made it necessary to design steam producers to supply tremendous amounts of steam in such a way that a minimum of space will be occupied, which together with the progressively increasing demand of turbine manufacturers for higher steam pressures and temperatures has forced the remarkable development of both the heat-producing and heat-absorbing apparatus.

In the days of reciprocating engines the boiler room was relatively small compared to the engine room, but now the reverse is true in even greater ratio. The result has been that intensive study and exceedingly numerous and expensive experiments of various kinds have been made involving fuel-burning apparatus and furnaces that will produce heat sufficient to give evaporations of as much as four or five times what would, but a very few years ago, have been considered normal rates. This again has created other problems of heat absorption, furnace-wall maintenance, fuel control, etc. that have resulted in many exceedingly ingenious, effective, and efficient pieces of apparatus.

Another factor that has contributed to this end has been the increasing cost of fuel, so that to a far greater extent than ever before it pays to invest in apparatus for saving relatively small percentages of the heat otherwise wasted, thus reducing fuel loss to a minimum. Of course, there is always a dividing line where further saving does not justify the cost of the means needed to effect that saving.

Changes in Shape and Design Due to Use of Higher Pressures

Generally speaking, the shape and design of the pressure parts of boilers have not greatly changed from the old forms with possibly one or two exceptions. The most outstanding one of these is the steam generator, which is distinguished by the feature that it absorbs most of the heat by radiation. This is done by employing high heat head and violent turbulent combustion in combination with highly heated air. Where heat is to be absorbed rapidly by radiation it must be generated rapidly. These features characterize the steam generator.

For pressures up to 450 or 500 lb. per sq. in., the older methods of riveted construction are not especially objectionable nor particularly difficult to continue. This has meant the installation of far more powerful fabricating equipment and very much greater care in methods of workmanship. The thicker plates required to carry the higher pressures preclude the possibility of many of the old boiler-shop processes, such as laying up surfaces metal to metal by sledging. Precise forming by powerful tools and machine-shop rather than boiler-shop methods have been extensively introduced. The same qualities of material are still largely used in the fabrication of boilers for what may now be termed the more moderate pressures, although these would but a few years ago have been deemed high pressures. The dimensions of these materials, however, have grown tremendously.

For what we now call high pressures, say, 650 lb. and up, riveted construction is not advisable, and other methods of making the pressure parts are being evolved. The principal one so far is the forged seamless cylinder usually having the heads integral with the shell, which makes a most excellent piece of work although exceedingly expensive.

It is probable, too, that for the zone ranging from 400 to 800 lb., forged-welded vessels may be more extensively used, although this is not true to any great extent at the present writing. Vessels fabricated in this way may be made without the use of riveting of any sort, the heads, nozzles, etc. all being welded on so as to make a completed part of very good workmanship and without objectionable thicknesses due to the presence of butt straps, doubling plates, etc. as are necessary with riveted construction.

Tube thicknesses proportional to the higher pressures are necessary, but fortunately the coefficient of heat transmission of mild steel and the rate of heat absorption by water in contact with clean metallic surfaces are such that no overheating of the metal results. This is possible only by reason of the rather general use of either well-treated raw feedwater or the use of a very large percentage of condensate and make-up from evaporators, so that the wetted surfaces remain, over long-continued periods of time, practically clean. Fortunately, too, there has been no need to meet these modern pressure conditions by changing the method of attaching tubes to the other parts of the boilers. Rolling still amply suffices. The holding power of a tube is practically proportional to the area of contact of the tube with the circumference of the hole. This, however, is increased considerably by the use of grooves into which the wall of the tube is pressed during the rolling process. Expanding tube ends in their holes by means of roller expanders will probably continue to be the common practice. Here the ingenuity of manufacturers of tube expanders has been brought into play in evolving tools that are practicable for use with plate thicknesses of over 4 in. for 1200 to 1400 lb. pressures, in which cases the holes are usually made in a special way, as well as for thicknesses of $1^1/_2$ in. and 2 in. for the somewhat lower pressures. This item is only one of a myriad of practical but highly specialized problems that have forced themselves on the boiler manufacturers and which in turn have been passed to the makers of such special tools and appurtenances as are required for the fabrication and operation of a boiler.

In building boilers with these thick plates, the use of drills is universal, punching having been entirely superseded. This refers to both rivet and tube holes.

Moderate-Size, Moderate-Pressure Boilers in the Majority

It should not be assumed from the foregoing that high pressures are as yet universal. There is still a very great demand for boilers of the more moderate pressures, not the moderate pressures of ten years ago but those of today, say, from 200 to 350 lb., and, indeed, for still lower pressures. All of these, too, in unit sizes of from, say, 1500 sq. ft. of heating surface up to 15,000 sq. ft. Practically complete statistics of the boiler-making industry gathered by the U. S. Department of Commerce show that for the first six months of 1927 the average size of water-tube boilers was about 5700 sq. ft. of heating surface, which indicates that there are far more boilers of the relatively small sizes manufactured than of the very large sizes.

There is at present rather a keen rivalry between the merits of the slightly inclined straight-tube water-tube boilers and those of the vertical bent-tube type. The use of the latter is increasing, and it is often the preferable one due to the changes in modern conditions. There is a great variety of factors to be taken into consideration in determining the preferable type of boiler for any particular case, but it is possible to build boilers of either of the types for whatever pressures may be desired.

While central-station power is unquestionably being more and more extensively used for manufacturing purposes, it is also unquestionably true that most industries, particularly those where considerable amounts of steam are needed for heating and process purposes, can make their own power cheaper than they can purchase it, and it is because of this that the boiler-manufacturing industry survives. With the growing appreciation of these possibilities by consulting engineers, plant managers, operating engineers, etc. the rehabilitation of many industrial plants is being brought about.

Furnace Improvements Brought About

The high rates of combustion now so generally prevalent have

---

[1] Vice-President and Chief Engineer, Heine Boiler Co. Vice-President, A.S.M.E.

Presented at the First National Meeting of the A.S.M.E. Fuels Division, St. Louis, Mo., October 10 to 13, 1927.

made necessary tremendously enlarged dimensions of the furnace or space in which the fuel is burned. This has come about through appreciation of the fact that the combustible gases distilled from the fuel must be completely burned before any great cooling is effected. In the efforts to attain high efficiency the necessity of using the least possible amount of excess air is thoroughly recognized. This, in turn, results in exceedingly high furnace temperatures. Modern fuel-burning apparatus is designed to use but a small amount of excess air as compared with the old methods. With the latter, the refractory lining of the furnace was such that it would stand the temperatures more or less satisfactorily and for periods of sufficient duration to justify its use.

The modern method, however, with its resulting high temperatures, coupled with the very much greater extent of exposed wall surface due to the increase in furnace size, brought in its train serious complications in the way of wall construction and maintenance. The first palliative offered was in air-cooled walls, but these did not meet all needs, and the so-called water wall was evolved. This has been rapidly developed, largely by experimentation, so that now the proper requisites for the size and number of the circulating connections, as regards the water supply and the steam outlet, cross-sectional areas of headers, etc. are fairly well known. Directly connected with the boiler, these water walls become essentially a part thereof.

Being under full boiler pressure they must be carefully and properly designed and arranged. The total overall dimensions of the boiler and water-wall pressure parts are now, even in the case of moderate-size units, so great that the problems of expansion and contraction are serious and must not be lost sight of in the general design. Changes in temperature inevitably involve changes in dimensions and not infrequently in shape, and unless adequate provision is made to accommodate these changes, serious damage is likely to result.

While the introduction of water walls was primarily stimulated for the purpose of reducing setting maintenance, it has resulted in the increase of steam-making surfaces. These surfaces are heated almost entirely by radiant heat. Evaporation of water per square foot of surface of water-wall tubes is far in excess of that of any of the boiler heating surface with the exception of the rows of tubes immediately exposed to the furnace.

In one sense, the water wall may be considered a part of the furnace and one of its problems, and hence concerns the designer of fuel-burning equipment, but it is also a part of the boiler manufacturer's problem, and because of this combination of circumstances close coöperation between the two is very necessary.

While the absorption of heat begins in the furnace it goes on progressively and decreasingly with the flow of the gases through the gas passages of the boiler. The longer the gases can be kept in contact with the heating surface the more heat will be absorbed, but as the rate of transfer varies approximately with the difference in temperature between the gases and the water and the velocity of the gas, the amount of heat absorbed in the last part of the path is relatively very small.

Draft Problems

Inasmuch as the tremendous volumes of gas to be handled through restricted and very highly obstructed passages result in high friction loss, mechanical methods of creating drafts are generally necessary. To so baffle a boiler as to reduce the outlet temperatures to a very low point results in a very high draft loss, whence the practice of permitting a relatively high gas outlet temperature from the boiler and effecting a further abstraction of heat from the gases by means of economizers and air preheaters is rapidly growing. The investment represented in apparatus of this sort is far less than in the boiler proper. To the extent that the loss of heat units up the chimney is prevented, the overall efficiency is benefited.

Not infrequently both economizers and air preheaters are installed, although with a properly baffled boiler, depending upon other factors such as methods of heating feedwater by turbine bleeding, etc. one or the other is ordinarily sufficient.

The combined boiler, superheater, water-economizer, and air-heater surfaces offer sufficient resistance to the gas flow to require the use of induced- and forced-draft fans in most cases. The proportioning of work to be done in the boiler, superheater, water economizer, and air heater can be determined only after a consideration of all the factors such as cost of fuel, load factor, cost of real estate, etc. In general it resolves itself down to the selection of a combination of equipment that will show a return on the investment under the plant load and operating conditions.

The air preheater carries the retrieved heat back into the furnace but reduces the amount of heat necessary to bring the incoming air up to the temperature necessary for combustion, thus expediting the ignition of the fuel and raising the furnace temperature.

Water walls have not only added to the steaming capacity of the boiler but have reduced the setting to merely a light enclosing structure in which often both firebrick and red brick may be omitted altogether, a sheet-iron casing with a non-conducting lining outside of the water-wall tubes being sufficient. With this arrangement radiation and air leakage have practically disappeared as one of the serious items in a heat balance.

Increase in steam temperatures beyond that due to the pressure is a mounting factor, and the details of boiler design have had to be considerably modified to accommodate superheaters sufficiently large to give the desired temperatures. In order to avoid a cumbersome piece of apparatus the practice of locating superheaters in zones of relatively high temperature is becoming common, and the so-called radiant-heat type located directly in the furnace is not at all unusual. This latter service is extremely severe, due to the slow heat-absorbing properties of steam, so that the shielded radiant type and the convection type of superheater in contact with gases of more moderate temperatures are the preferred ones.

Furnace Control

In order to maintain as uniform furnace conditions as may be possible, even with varying demands for steam, a number of furnace-controlling systems have been designed. Many of these are exceedingly ingenious and very effective, and are promptly responsive to changing conditions. The mechanism and adjustments are for the most part rather delicate, and must therefore have intelligent care. Devices of this sort cannot be made foolproof nor to take care of themselves.

Indeed, the modern power plant, regardless of its size, requires a much higher type of supervision and attendance than was thought necessary under the older and less exacting practice.

The functioning of a boiler is a complicated process influenced by a great variety of factors. It is advisable in even relatively small plants to have sufficient measuring and indicating instruments to determine what is going on at all times in all the processes concerned with boiler operation. A few of these items are CO_2 in escaping gases, draft loss through the boiler, temperature of escaping gases, temperature of feedwater, steam pressure, superheated-steam temperature, pressure in furnace (plus or minus), forced-draft air pressure, etc. In an intelligently operated plant of whatever size, with the proper equipment of instruments, it is possible to give the boiler-room attendant certain relatively simple directions that will enable him to keep the boiler operating with fairly continuously uniform efficiency.

Where the size of the plant does not justify a high degree of complication of apparatus, the question of where to draw the line is one that can be fairly closely and accurately determined by a careful analysis of all the contributing factors, and the determination may, for instance, very possibly result in the adoption of a chimney and the retention of natural draft rather than the employment of induced draft, and lower rates of combustion with less complicated fuel-burning apparatus, etc. But as above suggested, it is essential that there be provided some indicating instruments in addition to steam and water gages, by which at least a fairly complete knowledge of what is going on may be obtained.

Methods of calculation of the various problems and the relationship of various factors entering into boiler operation have now been brought to a point where predictions of performance can be made—not with exactness but within narrow limits of error—that make it possible to determine beforehand fairly accurately what the results should be. Thus it is possible to design a boiler which is adapted to the service for which it is intended, and to attain that degree of dollar efficiency which the circumstances warrant.

Application of Powdered Coal to Small Boilers of Industrial Plants

Certain Limitations in Design and Operation of Small Plants That Make Attainment of High Efficiencies Impractical—Examples of Application of Pulverized Coal to Industrial Plants, Some of Them Having Very Small Units

By HENRY KREISINGER,[1] NEW YORK, N. Y.

THE good results that are being obtained with powdered coal in large central stations have created an interest in powdered coal among the operators of small steam plants and small boiler units of industrial establishments. The small plants are usually stoker- or hand-fired, and the results are frequently far from satisfactory. The monthly operating efficiency seldom reaches as high as 70 per cent. When the operators of the small plants hear of the high efficiencies which are being obtained with large pulverized-coal installations, they feel that they should take advantage of the new developments in pulverized coal, reduce their coal bills, and increase the capacity of their plants.

Although the small plants can be benefited by the installation of powdered-coal firing, they cannot as a rule obtain the high efficiency that is obtained by the large central stations. There are certain limitations in the design and in the operation of the small plants that make the attainment of the high efficiencies impractical. This paper points out some of the limitations and gives a few examples of the application of pulverized coal to industrial plants, some of them having very small units.

It may be true that pulverized-coal burning was developed on small boilers, but most of the first new pulverized-coal installations with rational design of furnaces were made in large central stations on large steam generating units. The efficiencies obtained with some of these installations are high, averaging 88 to 90 per cent by the month. These high efficiencies were made possible because with these large units the designing engineer was justified in using such combinations of apparatus as could be operated with high efficiency. To obtain a good heat absorption the designer used large economizers or a combination of a smaller economizer and air heater. To obtain good combustion he designed large, well-proportioned furnaces with water-cooled walls. This design of furnace made it possible to burn the coal with low excess air, easy ash removal while the furnace was in operation, and small furnace maintenance.

These large installations also use the storage or bin system, which gives conditions more favorable to high efficiency. The roller mills used with the bin system, being independent of the furnace requirements, are operated at nearly constant capacity and produce coal of uniform fineness. The fineness does not change with the wear of the coal-pulverizing parts of the mill. The feeder and bin system lends itself to a close adjustment of the air and coal supplied to the furnace, which, together with the uniform fineness of the coal, promotes better combustion. With this system the furnace is independent of the mills, and therefore can be operated without interruptions from the breakdown of the mills or renewals of the worn-out parts. There are, therefore, fewer unnecessary banking periods of the steam-generating units and smaller banking losses.

Although with powdered-coal firing there is very little or no coal burned during banking periods, nevertheless there are losses from radiation and from heat being carried up the stack by the unavoidable flow of air through the setting. The setting is cooled off, and when the unit is started heat is put into the setting during the time it is heated to operating temperatures.

Improvement of Small-Plant Efficiency Generally Possible Through Use of Pulverized-Coal Firing

Generally speaking, the small-plant operator can appreciably improve his operating efficiency by using pulverized-coal firing. However, he cannot obtain the high efficiency and the greater capacity that is obtained with the large installations. The size of his plant does not justify him in putting in the best combination of equipment such as is used in the large central stations. The cost would be prohibitive. The small-plant operator can buy only such equipment the cost of which will be justified by the size of the plant and the saving in coal that can reasonably be expected.

The small plant is usually a part of a manufacturing establishment and its financing is done on different basis as to the rate of return on the investment from that which is the case with large plants of public-utility companies. The calculations on the costs and possible returns with the industrial plant must show frequently nearly double the rates of the public-utilities returns before financial backing can be obtained. As a result of this different basis of financing, many of the industrial plants must go without economizers and air heaters. Even the heating surfaces of the boilers may have to be reduced. Thus the products of combustion are allowed to escape at a comparatively high temperature, making it impossible to obtain high efficiency.

Factors Causing Poor Combustion Conditions

In the effort to keep the first cost down the furnaces of the small plant must forego the advantages that can be derived from air- or water-cooled walls and bottoms. The furnaces may have to be built with solid brick walls and flat bottoms, which construction makes it necessary that they be operated with high excess air in order to avoid erosion of the walls and to make ash removal possible without shutting down the boiler. Such operation of course results in lower efficiency.

For the same reason of the necessity of low first cost, the storage or feeder and bin system is barred out and the direct firing system, which is admittedly less efficient, must be used. Although the direct firing under favorable test conditions can show a good efficiency comparable to that of the storage system, this good efficiency cannot be maintained over long periods of operation. Most of the mills used for direct firing are of the high-speed beater type. As the pulverizing parts wear, the capacity of the mill is reduced, and at the same time the pulverized coal becomes coarser. At times the operator may find it necessary to hold the capacity, which he may succeed in doing at the sacrifice of fineness, with the result that excessively coarse coal is supplied to the furnace. The coarse coal does not burn completely and either falls to the bottom where it accumulates without burning completely, or is carried up the stack, thus causing high incomplete-combustion losses and low efficiency.

Another factor which may cause poor combustion condition is irregular feeding to the mill due to either excessive moisture in the coal or variation in the size of coal. A lump of coal or a piece of wood or iron may stop the feed entirely and cause the fire to go out before the operator is able to remove the obstacle from the feed, and it may then be necessary to light the fires with a torch. Such conditions increase the incomplete-combustion losses, thereby lowering the efficiency.

The small industrial plant may be operated only during the daytime and remain banked a large part of the night. If the fires in a banked boiler are started at six in the morning it may be one or two o'clock in the afternoon before the setting becomes heated and all the heat generated in the furnace becomes available for making steam instead of being partly absorbed by the setting. The heat absorbed by the setting during the first part of the day

[1] Research Engineer, Combustion Engineering Corporation. Mem. A.S.M.E.

Presented at the First National Meeting of the A.S.M.E. Fuels Division, St. Louis, Mo., October 10 to 13, 1927.

is largely lost after the boiler goes on bank in the evening. The average efficiency for the day's run may be two or three per cent lower than it is during the afternoon after the setting becomes thoroughly heated.

Loss in Operating Efficiency Resulting from Long Banking Periods

Fig. 1 is the efficiency curve of a powdered-coal-fired boiler starting from a banked condition at 6:30 a.m. and going on bank again at

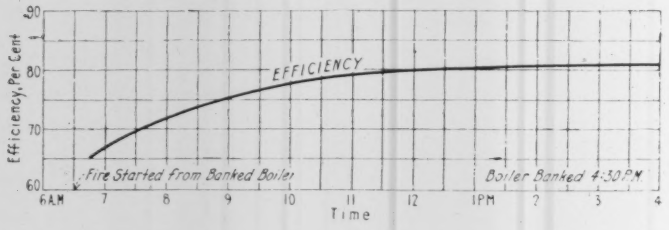


FIG. 1 EFFICIENCY CURVE OF A 1000-HP. HORIZONTAL-WATER-TUBE POWDERED-COAL-FIRED BOILER STARTING FROM BANKED CONDITION

4:30 p.m., remaining banked from 4:30 p.m. until 6:30 a.m., a total of 14 hours. During the ten hours of operation the average rating on the boiler was 180 per cent. This was the regular operation during five working days in a week. Saturdays and Sundays the boiler remained banked throughout.

The boiler was a 1000-hp. horizontal water-tube Wickes boiler at the plant of the Farr Alpaca Company, Holyoke, Mass. It was vertically fired by the feeder and bin system. The furnace walls were of the hollow-wall air-cooled construction and the bottom was cooled by a water screen. It was one of five similar boilers at this plant and was without an economizer or an air heater. It cannot be called a small boiler. It is referred to because of its comparatively short period of operation and long period of banking. Its operation illustrates the loss in operating efficiency due to long banking periods. The curve shows that the efficiency during the first two hours of operation after lighting the fires was only about 69 per cent, although after the setting became thoroughly heated it reached 81 per cent. The weights of the coal burned and the water fed to boiler were determined by actual weighing for each two-hour period. Fifteen such tests were made, and all of them gave an efficiency curve similar to that shown in Fig. 1. It is safe to say that had the boilers been fired with stokers the operating efficiency would have been much lower, although when compared with the operating efficiency of some of the large central stations, the efficiency of this boiler appears low.

It may appear that the substance of this paper is an argument against the application of powdered coal to small industrial boilers, but such is not the case. The author is merely pointing out some of the reasons why the owner of a small plant with small boilers cannot obtain the high efficiency that is obtained in some of the large central stations. If the small-plant operator with his low-cost equipment and unfavorable operating conditions were made to believe that by the use of pulverized coal he could obtain as high efficiency as the large plant, he would be doomed to disappointment. He should realize that with his equipment and his unfavorable operating conditions, 75 per cent operating efficiency is quite creditable, and cannot be obtained by other methods of firing.

Typical Installations of Powdered Coal Under Small Steam Boilers of Industrial Plants

The following illustrations show five typical installations of powdered coal under small steam boilers of industrial plants.

Fig. 2 shows an installation of powdered coal under a horizontal tubular boiler having 1830 sq. ft. of heating surface. It is one of two similarly fired boilers at the nursery of A. H. Budlong, Chicago, Ill. The boilers supply steam for heating glass houses and for pumping water for irrigation purposes. The heating season is ten months long. Steam is also used on cold nights during the remaining two months.

Coal is pulverized by a Raymond impact mill driven by a steam turbine. The pulverized coal is discharged directly into the furnace and burned by means of a Leach burner. The operating rate of

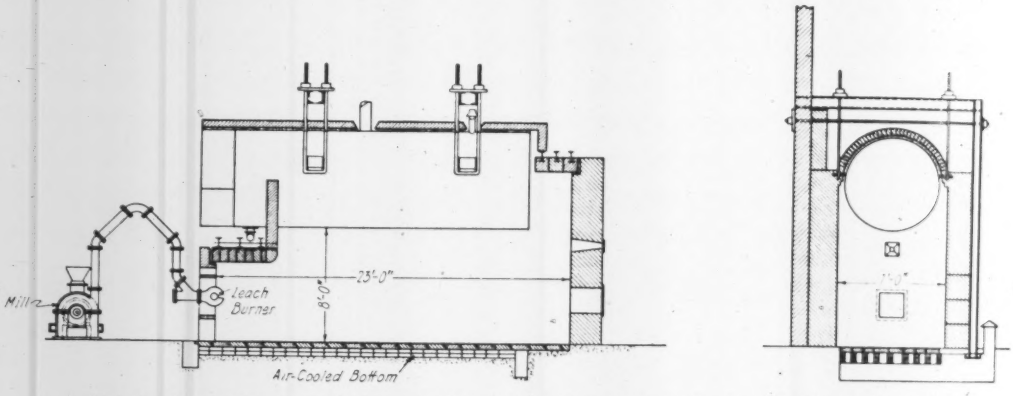


FIG. 2 APPLICATION OF POWDERED COAL TO A HORIZONTAL RETURN-TUBULAR BOILER

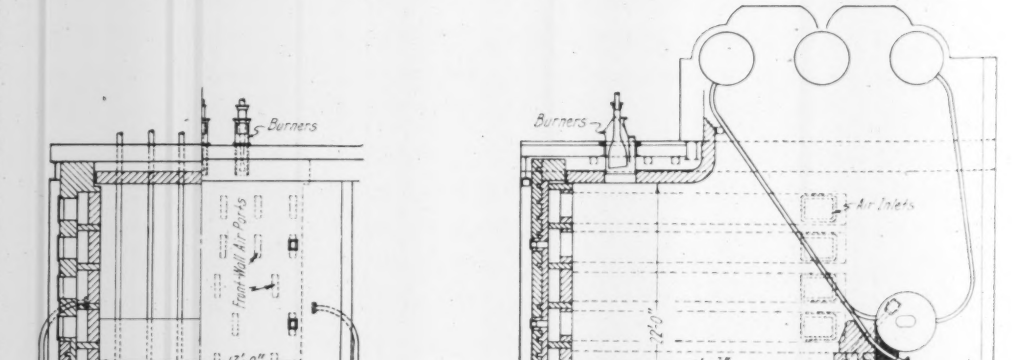


FIG. 3 APPLICATION OF POWDERED COAL TO A STIRLING BOILER

combustion varies from 235 to 1100 lb. of coal per hour. The exhaust steam from the turbines driving the mills is used in the heating system.

The boilers are kept in service about three months at a time before they are taken off the line for general cleaning inside and out. The plant has been designed for continuous operation. Mill repairs during the heating season consist only in changing the hammers. A set of hammers has been changed in eleven minutes from the time the turbine has been shut down to starting it up again. Major replacements are made in the summer.

The operation of this installation has been very satisfactory.

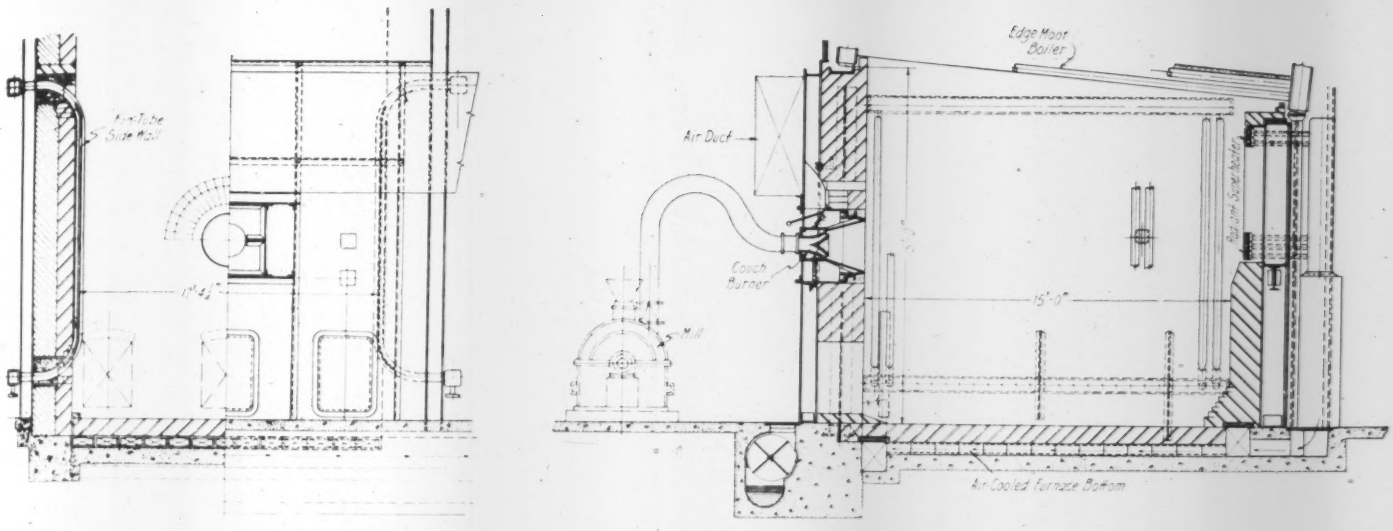


FIG. 4 APPLICATION OF POWDERED COAL TO AN EDGE MOOR BOILER

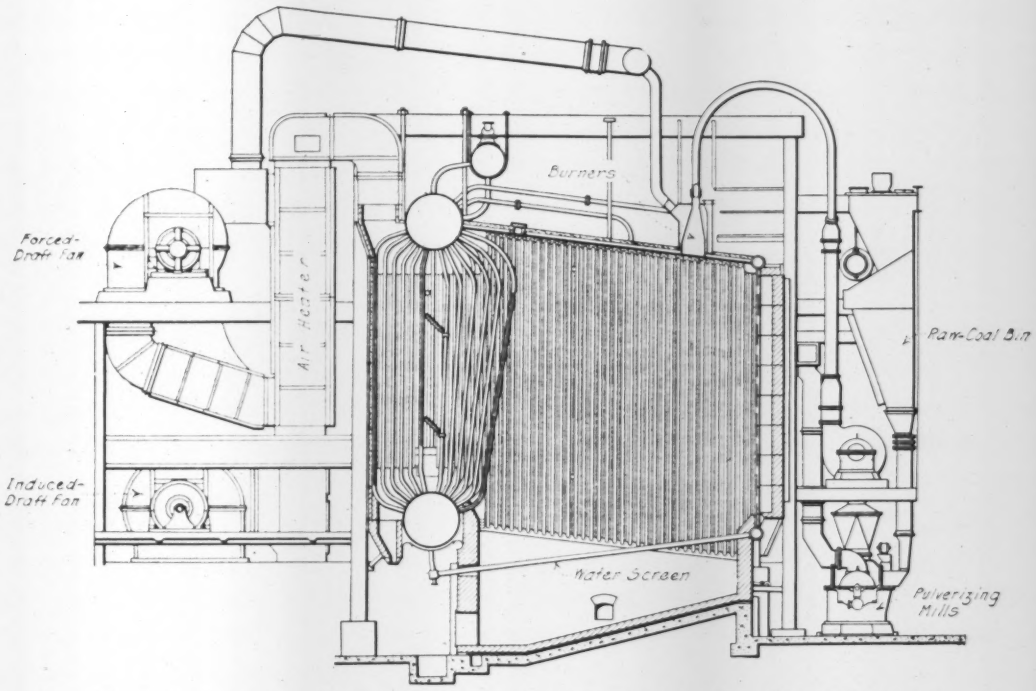


FIG. 5 APPLICATION OF POWDERED COAL TO A LADD BOILER WITH WATER-COOLED FURNACE

The content of CO_2 in the flue gases varies from 12 to 16 per cent, and depends on the rate of working. With the high rates of working and high percentage of CO_2 there is a tendency for the ash to fuse, which should be expected with Illinois coal and the type of furnace used.

Table 1 gives the principal data of this installation.

Fig. 3 shows an application of powdered coal to two small Stirling boilers at the plant of Pejepscot Paper Company, Lisbon Falls, Me. The two boilers are set in a battery with brick air-cooled furnace walls and bottoms. Storage system is used at this plant. Plant operates continuously six days a week and is shut down over Sunday. Table 2 gives the principal data of this plant.

Fig. 4 shows a powdered-coal application to one of the three Edge Moor horizontal water-tube boilers at the plant of Cushnoc Paper Company, Augusta, Me. At this plant the boilers are fired by the direct-firing pulverized-coal system. They are fired horizontally with one Couch burner to each boiler. One of the furnaces has fin-tube water-cooled side walls, whereas the other two have air-cooled hollow walls. All three furnaces have air-cooled furnace bottoms and radiant superheaters in the rear wall. Table 3 gives the principal data of this installation.

Fig. 5 shows a two-drum Ladd boiler equipped with air heater and water-cooled fin-tube furnace at the plant of the Atlas Portland Cement Company, Northampton, Pa. It is fired with powdered

TABLE 1

Installation	A. H. Budlong, Nursery, Chicago, Ill.
Object of plant	Heating glass houses for cultivation of flowers and pumping water for irrigation purposes.
When installed	1925.
Number and size of boilers	Two horizontal return-tubular boilers, 72 in. in diameter, 18 ft. long and containing 1839 sq. ft. of heating surface each.
Number and size of tubes	124 3 in. tubes.
Kind of setting	Brick, partly air-cooled side wall and bottom of furnace.
Method of firing	Direct firing pulverized coal.
Width of furnace	7 ft.
Height of furnace	Bottom of shell to bottom of furnace, 7 ft. 10½ in. rear, 8 ft. 0 in. front.
Length of furnace	23 ft.
Kind of pulverizing mill	Two Raymond No. 3 impact mills.
Capacity of each mill	1400 lb.
Method of driving mills	Steam turbine direct connected, 1800 r.p.m.
How started when boilers are cold	Cold furnace can be started with ball of oily waste on a rod. However, 20 lb. of steam is required to start turbine, so if both boilers are cold, one must be started with wood fire to raise 20 lb. of steam to run turbine.
Number and type of burners	One 8-in. Leach burner per boiler, horizontal firing.
Load on boilers	Maximum winter load 12,000 lb. of steam per hour. Minimum load during warm weather, 2400 lb. of steam per hour intermittently.
Continuity of operation	Boilers on for three months at a time.
Approximate efficiency	78 to 80 per cent at 150 per cent of rating.
Coal used	Illinois No. 5 size.
Is installation satisfactory?	Yes, very.

coal by the direct-firing system, using vertical firing and Lopulco burners. The boiler is kept continually in service for a month. It is then taken off the line and thoroughly washed inside on account of bad feedwater. Table 4 gives the principal data of this unit.

Fig. 6 shows a powdered-coal application to two B. & W. horizontal water-tube boilers. This installation uses the direct-firing system. Coal is fired horizontally with a Couch burner. Table 5 gives the principal data of this installation.

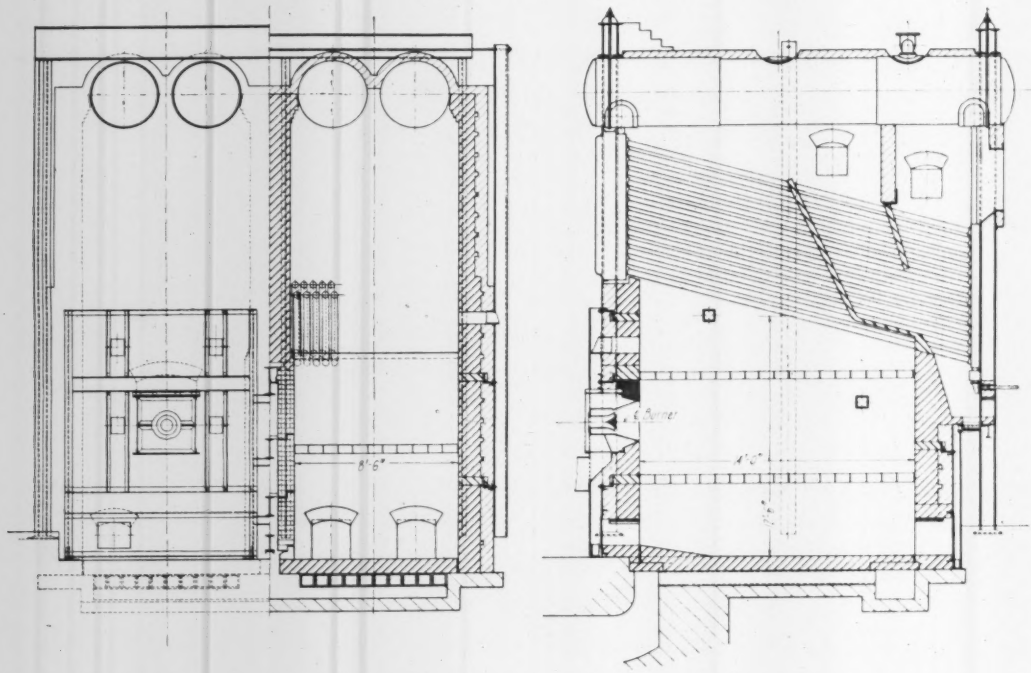


FIG. 6 APPLICATION OF POWDERED COAL TO A BABCOCK & WILCOX BOILER

TABLE 2

Installation	Pejepscot Paper Company, Lisbon Falls, Me.
Object of plant	Steam for power and process.
When installed	1924.
Boilers	Two Stirling; 3750 sq. ft. of heating surface each; brick furnace with air-cooled hollow walls and water screen over the furnace bottom.
Furnaces	2170 cu. ft. of furnace volume; vertically fired; storage system.
Mills	One Raymond 6-roll, 6 tons per hour capacity; No driers used; coal dried in mill using hot flue gas.
Burners	Two Lopulco burners to each boiler.
Rating	14,000 to 28,000 lb. steam per boiler per hour.
Service	Operates 24 hours, 6 days a week. Plant idle on Sundays.
Efficiency	80 to 81 per cent.
Coal used	New River.

TABLE 3

Installation	Cushnoc Paper Company, Augusta, Me.
Object of plant	Steam for power and process.
When installed	1926.
Boilers	Three Edge Moor horizontal water-tube boilers, 6000 sq. ft. of heating surface each.
Furnaces	One furnace has water-cooled fin-tube side walls, and a radiant superheater in the rear wall. The other two have air-cooled hollow walls with radiant superheater in the rear wall; furnace volume, 2800 cu. ft.; all three furnaces are direct-fired.
Mills	One No. 50 Raymond impact mill to each boiler; capacity, 4500 lb. of coal per hour; motor driven.
Burners	One Couch burner firing horizontally to each boiler.
Load	30,000 to 36,000 lb. of steam per hour per boiler.
Service condition	24 hours per day for 6 days a week; plant shut down Sundays.
Efficiency	78 per cent.
Coal used	Pocahontas slack.

TABLE 4

Installation	Atlas Portland Cement Company, Northampton, Pa.
Object of plant	Steam for power for manufacturing cement.
When installed	1926.
Type of boiler	One 2-drum Ladd boiler; boiler heating surface 7200 sq. ft.
Type of furnace	Water-cooled fin-tube side walls and roof. Water-cooled tubes and refractory front wall; water screen over bottom of furnace. water-cooled furnace surface, 2150 sq. ft.
Air heater	24,480 sq. ft. heating surface.
Width of furnace	24 ft. 6 in.
Length of furnace	Front to rear, 20 ft.
Height of furnace	Roof to water screen, 20 ft.
Method of firing	Direct firing, vertically downward.
Number and type of burners	Eight Lopulco burners.
Kind of pulverizing mills	Two No. 70 Raymond impact mills.
Load on boiler	60,000 to 140,000 lb. of steam per hour.
Coal used	Pennsylvania high-volatile bituminous coal.
Approximate efficiency	81 per cent operating efficiency by the month.

TABLE 5

Installation	American Writing Paper Company, Holyoke, Mass.
Object of plant	Steam for power and process.
When installed	1926.
Boilers	Two B. & W. horizontally fired water-tube boilers, 4000 sq. ft. of heating surface each.
Furnaces	Solid brick-wall furnace; volume, 1386 cu. ft.; direct fired; horizontal burners.
Mills	Two No. 40 Raymond impact mills, one to each boiler; capacity of each mill, 2500 lb. per hour.
Burner	One Couch burner to each boiler.
Load	24,000 lb. steam per hour.
Efficiency	76 per cent.
Coal used	Pocahontas.

Heads of industries from 35 industrial States of the Union met on September 14 at the Waldorf-Astoria Hotel, New York, in the organization meeting of the Platform of American Industry Committee on One Hundred, brought together under the auspices of the National Association of Manufacturers. The committee drafted a national platform to be submitted to the manufacturers of the nation at their October convention in Chattanooga and later to be placed before both the Republican and Democratic conventions as guiding principles which industry believes any national administration should take cognizance of for the best interests of the country. Suggestions have been submitted to the association for planks in the platform, and the tentative subjects include: Government ownership and participation in business; American merchant marine; disarmament; industrial preparedness and national defense; taxation; immigration and naturalization; tariff; judiciary; flood control; foreign trade policies; conservation of natural resources; agriculture; patent offices; revision of postal rates; Pan-Americanism; international relations and foreign debts; regulation of combinations; alien property; women in industry; railroads; waterways development; commercial aviation; highways; private employment relation; and juvenile education and employment.—*Iron Age*, vol. 120, no. 11, September 15, 1927, p. 700.

Mechanical Equipment Used in Driving the Moffat Tunnel

Particulars Regarding the Mechanical Equipment and Methods Employed in Driving This Six-Mile Timber-Lined Tunnel Through the Rockies 9000 Ft. Above Sea Level, the Pioneer System of Tunneling Being Used

By D. W. BRUNTON,[1] DENVER, COLO.

THE Rocky Mountain chain reaches its culmination in Colorado, as there are more square miles of mountain tableland above 10,000 ft. elevation and more mountain peaks above 14,000 ft. elevation in Colorado than in all of the other states in the Union. For this reason, the Union Pacific Railway in crossing the continent veered to the north, avoiding Colorado entirely and going through Wyoming, while the Santa Fe Railway for the same reason swung down to the south through New Mexico. In Colorado, the Continental Divide is crossed by the Rio Grande Western Railway in three places, but in doing so it traverses Tennessee Pass at 10,240, Marshall Pass at 10,856, and Cumbres at 10,015 ft. elevation. In addition to having to cross the Continental Divide at these high elevations, it has been necessary to zigzag across the state to obtain water grades by following the principal streams, which has increased the mileage to such an extent that the distance from Denver to the Utah state line on the main line of the Rio Grande Western is double the airline distance.

The Denver & Salt Lake Railway is now completed as far west as Craig, 255 miles from Denver, and crosses the Continental Divide through Corona Pass at an elevation of 11,660 ft., and to avoid this climb the Moffat Tunnel is now being constructed. During the winter months in Colorado, snowstorms do not seriously interfere with railroad operation up to 9000 ft., but above that elevation the snowfall increases rapidly and at the same time drifts more readily, and there are times when it is impossible to maintain regular train service no matter how many snowplows are put into service.

To determine the most available point for the tunnel, a 9000-ft. contour line was run on both sides of the range for thirty or forty miles to determine the closest approach of these lines to each other. On the best and most direct line between Denver and Salt Lake this point was found to be about three miles from Tolland, a station on the Denver & Salt Lake forty-seven miles from Denver where the old glacial valleys, now occupied by the Fraser River on the west side of the Continental Divide and South Boulder Creek on the east, come within six miles of each other.

The Pioneer System of Tunneling and Its Advantages

The pioneer system of tunneling (Fig. 1) had been so successfully used in the Simplon 12.4-mile tunnel in the Swiss Alps and the Rogers Pass 5-mile tunnel on the Canadian Pacific that it was decided to employ this method in driving the tunnel through the range at this point. An additional reason for the use of this system was that the pioneer tunnel, after the completion of the main tunnel, could be used as a conduit to carry water from the Fraser River to the eastern slope for the city of Denver.

When a pioneer tunnel is used in conjunction with a railway heading, the two are connected by a series of cross-cuts usually 1200 ft. apart, and the piping and supplies for the railroad heading are brought in through the pioneer tunnel and cross-cut instead of through the completed railroad tunnel. All traffic connected with driving the railroad heading is carried on through the pioneer tunnel, thereby entirely obviating interference with the work of enlarging the heading to full tunnel size.

When the rock is sufficiently hard to stand without support, the enlargement is carried on by what is known as ring drilling from the center heading, and in order that blasting may not interfere with drilling, the latter is usually kept several hundred feet ahead of the face of the bench (Fig. 1). The ring drill holes are usually four feet apart, and when shot, from three to four rings are loaded simultaneously and fired in quick succession by electric delay fuses. In order that the drill holes in each ring should be in a uniform plane, accurately spaced, and drilled to the correct depth, a circular plate was bolted to the drill column and on it the exact position of the drill for each hole was plainly marked (Fig. 2). By using this device the drill holes were accurately placed, which was far from being the case where the miners were allowed to use their individual judgment.

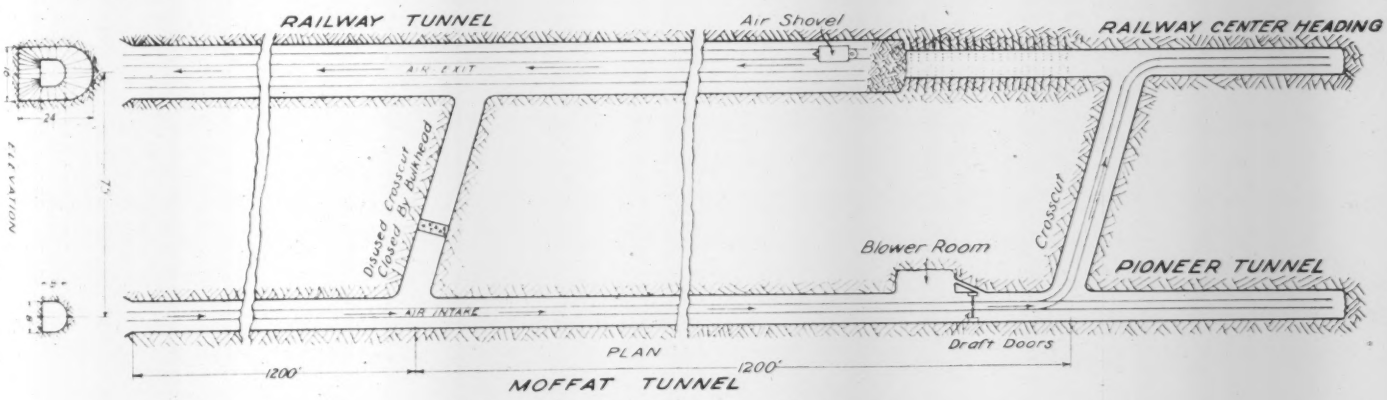


FIG. 1 THE PIONEER SYSTEM OF TUNNELING

The pioneer system of tunneling, in addition to its other advantages, greatly facilitates and cheapens ventilation, as the pioneer can be used as an air intake, while the main tunnel forms an exhaust conduit to carry off the products of explosion. In the workings from each portal two horizontal 16-cu. ft. impeller-type blowers are used, each operated by a 100-hp., 2200-volt electric motor geared to blowers with a jackshaft; capacity, 4000 cu. ft. of free air per minute at 4 lb. pressure. One of these blowers supplies air through a 12-in. pipe to the face of the pioneer tunnel, and the other blower, through a 12-in. pipe, carries the air to the face of the center heading. As these two streams of air force back the gases from the face of the headings, a draft door in the pioneer tunnel compels all of the gases to travel outward through a portion of the railway heading into the completed tunnel. As these gases have only had a dilution of 8000 cu. ft. per min., they would affect the health and comfort of the men working on the bench enlarging the railroad heading to the full-size tunnel. To obviate this, an electric-driven fan of 16,000 cu. ft.

[1] Chairman Consulting Engineers, Moffat Tunnel Commission. Mem. A.S.M.E.

capacity is used in conjunction with the blowers, but as its delivery pipe is only long enough to reach from the blower chamber on the side of the pioneer tunnel to the inner side of the draft door, the frictional resistance is slight and a few ounces pressure is amply sufficient. This additional amount of air dilutes the gases to such an extent that they are scarcely noticed by the workmen engaged on the enlargement.

AIR-COMPRESSOR EQUIPMENT

Compressed air for the workings from the West Portal is furnished by three 20 × 11 × 14-in. compressors; capacity 1126 cu. ft. of free air per min. Each compressor is operated by a 200-hp. synchronous motor running at 600 r.p.m.

FIG. 2 DEVICE USED IN RING DRILLING

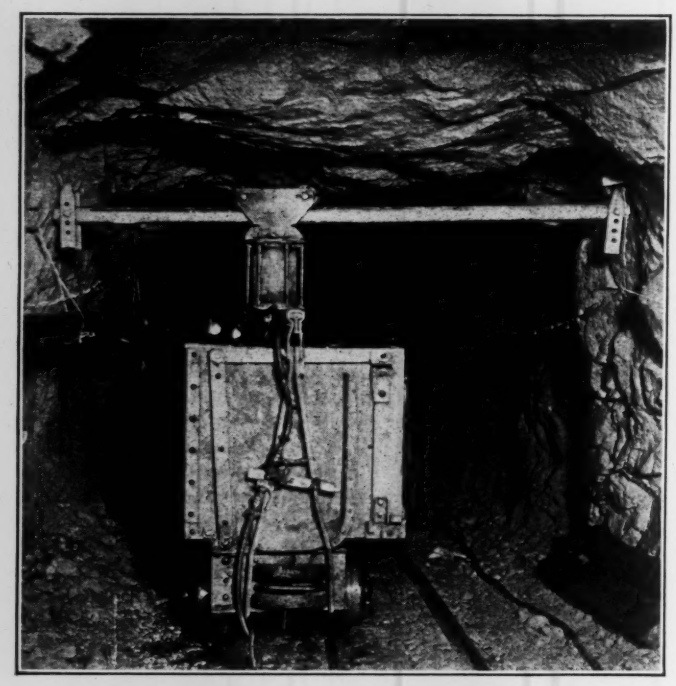


FIG. 3 PNEUMATIC CRAWL FOR SHIFTING EMPTY CARS IN PIONEER TUNNEL TO ONE SIDE TO ALLOW LOADED CARS TO PASS

There is also one 13 × 7 × 10-in. compressor, capacity 478 cu. ft. of free air per min., operated by a 75-hp., 2200-volt induction motor.

Compressed air for the machines at the East Portal is supplied by three 20 × 12 × 14-in. compressors, and one 20 × 11 × 14-in. compressor, each having a capacity 1126 cu. ft. of free air per min. These four compressors are each operated by a 200-hp. synchronous motor running at 600 r.p.m.

In addition to the above, there is also one 15 × 8 × 12-in. compressor, capacity 677 cu. ft. of free air per min., operated by a 75-hp., 2200-volt induction motor.

TRANSPORTING MUCK FROM TUNNEL HEADINGS

For transporting the muck from the pioneer and railroad tunnel headings, 24-in. gage cars of 50 cu. ft. capacity are used, which are hauled by storage-battery locomotives.

Ten-ton shovels with cast-steel locomotive frames, 24-in. gage, with 40-hp., 250-volt d.c. motors are used and found to be extremely satisfactory.

At first the empty cars were held on a siding and brought forward to the loading machine whenever the loaded car from the face was run past the switch. It was found, however, that it was difficult to keep the switch close enough to the face, and to avoid delay in tramming and consequent idle time on the part of the loader, a pneumatic crawl was designed (Fig. 3), in the use of which the empty car is brought up near the face immediately behind the car that is being loaded. When the loaded car is ready to be pushed back, the empty is picked up by the crawl and shoved over to one side to allow the loaded car to pass, and then pushed back and dropped on the track so that the idle time of the loading machine is greatly reduced, as it only requires a fraction of a minute to make the transfer.

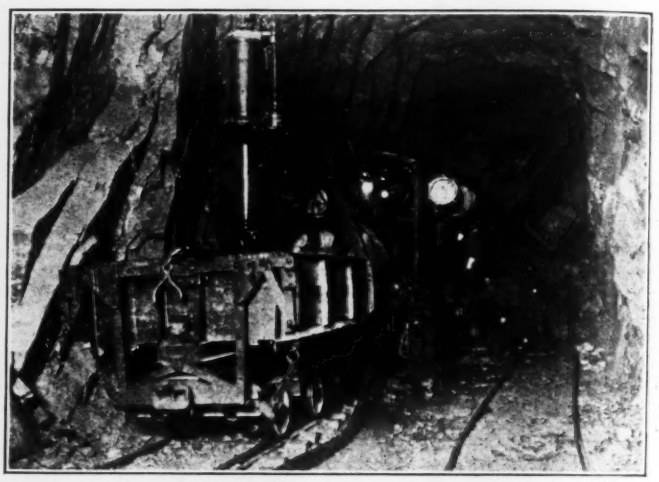


FIG. 4 DERRICK ON REAR END OF SHOVEL FOR PICKING UP EMPTY CARS AND DEPOSITING THEM ON LOADING TRACK

In the railroad tunnel, 36-in.-gage air shovels are used, the shovels being especially equipped with short booms, 11-ft. dipper sticks, and manganese-steel buckets of 1 cu. yd. capacity, and operated by compressed air at 90 lb. pressure, using a maximum of 1000 cu. ft. of free air per min. These shovels load directly into 36-in.-gage two-way dump cars of 4 cu. yd. capacity, built to special design for clearance.

The railroad tunnel is double-tracked, the shovel and the empty cars being kept on one track, the other being reserved for loading and loaded cars. To avoid the constant moving of switches, a derrick (Fig. 4) is placed on the rear end of the shovel which picks the empty cars up and deposits them on the loading track as fast as the loaded cars are pushed back from the front. This derrick performs practically the same service as the crawl in the headings, but of course is of much larger and heavier construction, and as it moves forward with the shovel it is always in the most desirable position for car shifting.

The contractors' 4-cu. yd. dump cars used in the tunnel are handled by 8-ton, 36-in.-gage electric locomotives. Some of these locomotives are equipped with automatic reels for gathering cars ahead of the trolley wire. They also use two 6-ton trolley locomotives and an 8-ton double-motor trolley locomotive; the last three locomotives were purchased second hand.

SUPPORTS USED IN WORKINGS

In the workings from the East Portal and in some of the ground encountered in the workings from the West Portal, the rock was

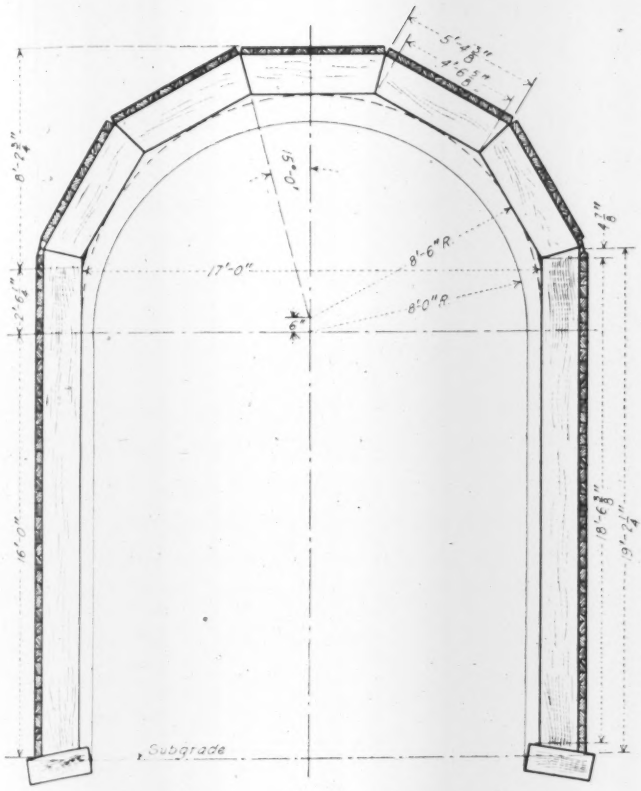


FIG. 5 TIMBER SUPPORTS FOR SOFT GROUND

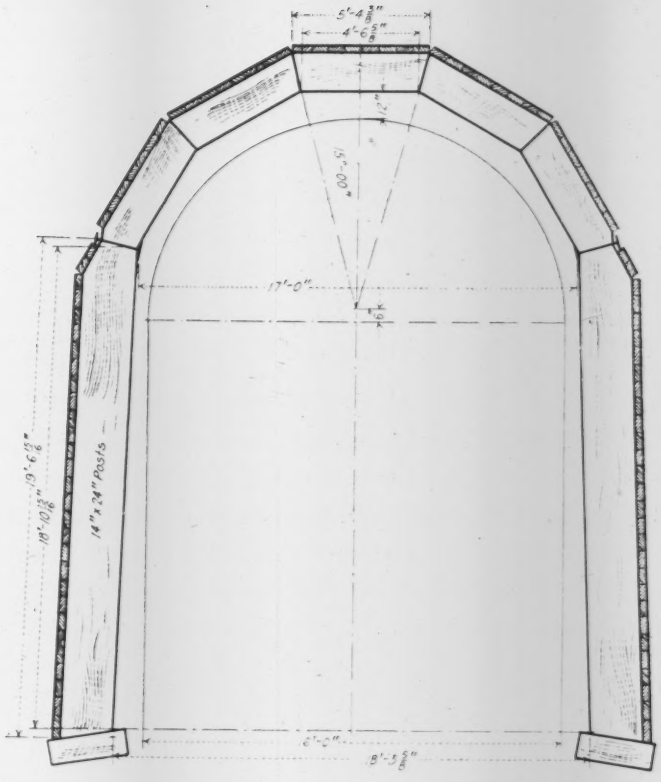


FIG. 6 TIMBER SUPPORTS FOR SOFTER GROUND THAN WHERE THOSE OF FIG. 5 ARE EMPLOYED

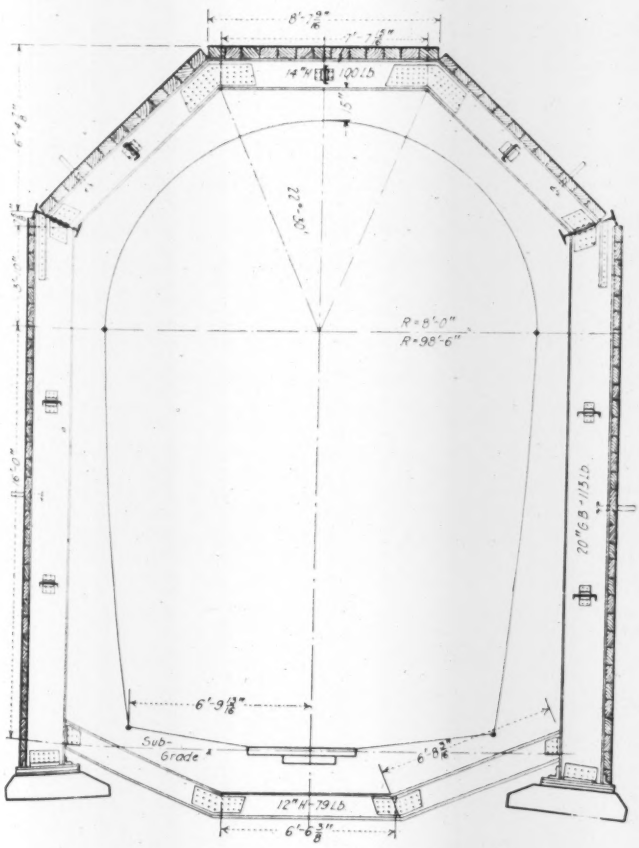


FIG. 7 20-IN. I-BEAM SUPPORTS FOR VERY SOFT GROUND

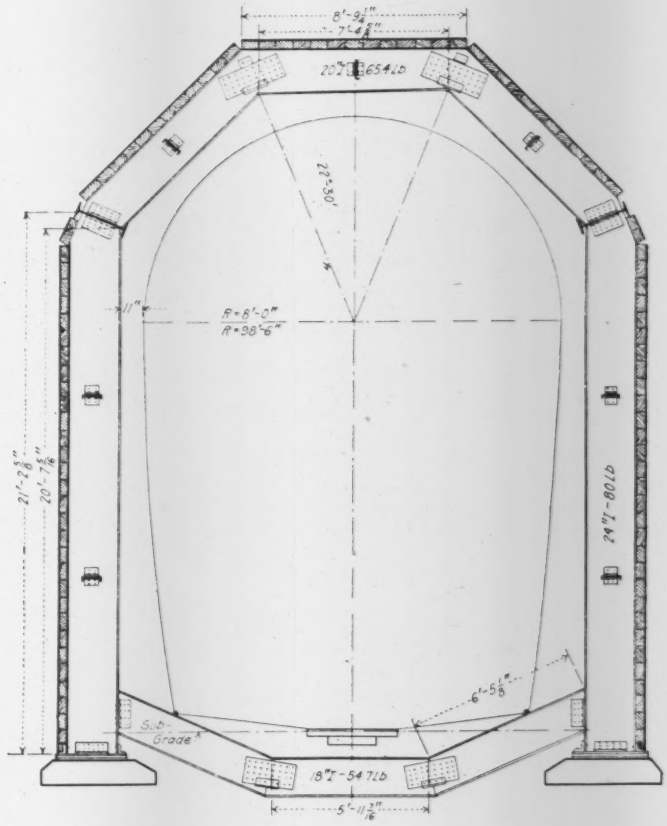


FIG. 8 24-IN. I-BEAM SUPPORTS FOR RESISTING THRUST DUE TO ROCK FLOWAGE NEAR CENTER OF TUNNEL

sufficiently hard to be self-sustaining, but unfortuantely in some places it had to be supported by 12 × 18-in. Oregon timbers (Fig. 5). As the headings from the West Portal advanced, the ground became softer and 14 × 24-in. Oregon fir timbers (Fig. 6) were used. When the ground became still weaker, timber supports were discarded and 20-in. I-beams (Fig. 7) used in their place. To keep the bottom

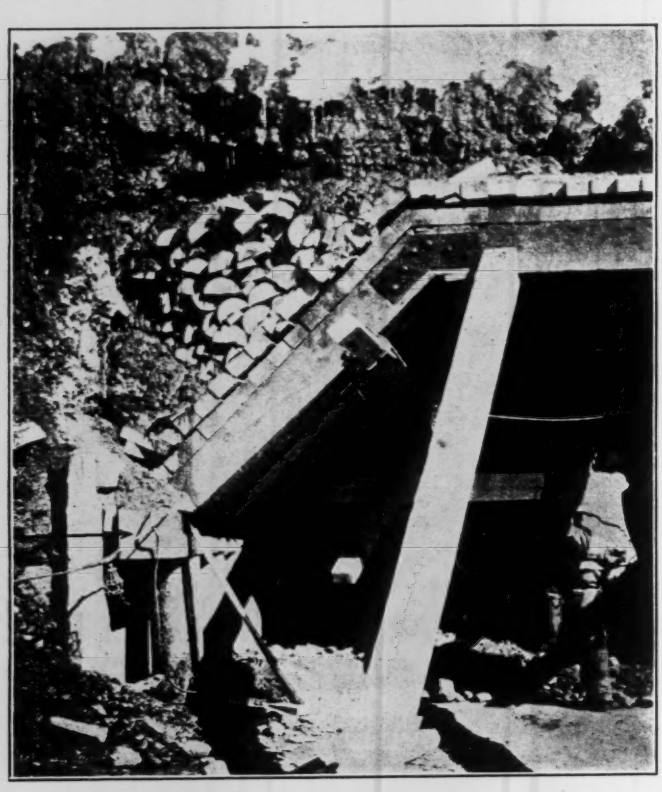


FIG. 9 TOP HEADING SYSTEM WIDENED OUT, ARCHES BEING SUPPORTED ON WALL PLATES

FIG. 10 RAKER POSTS USED IN EXCAVATING BENCH

from rising, a three-piece arch of 12-in. I-beams was used. Near the center of the tunnel, which is 2762 ft. below the crest of the range, rock flowage became so pronounced that 24-in. steel I-beam sets, 3 ft. apart, were required to withstand the thrust, and to prevent the bottom of the tunnel from rising a three-piece arch of 18-in. steel I-beams was required (Fig. 8).

Before the tunnel is used, the space between and in front of these I-beams to the net line (Fig. 8) will be filled with concrete, which will perform the double function of strengthening the arch and protecting the steel beams from rust.

Where the ground was sufficiently firm to stand without support, a center heading was used (Fig. 1), but where timbering was necessary, the top heading system was employed which was then widened out to the full width and the arches supported on wall plates (Fig. 9).

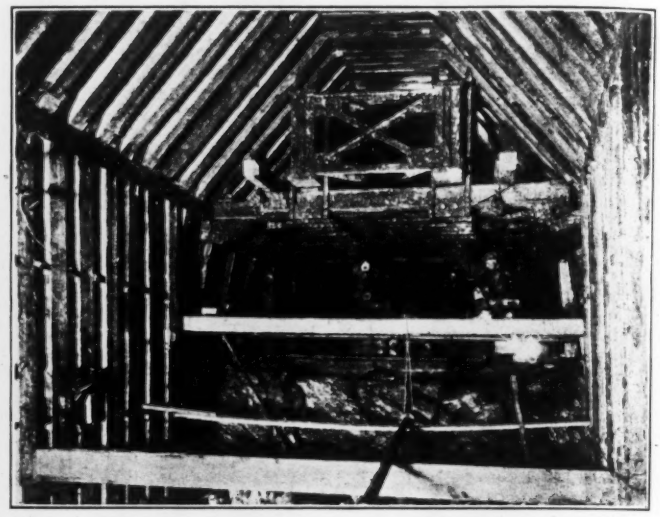


FIG. 11 THE LEWIS CANTILEVER

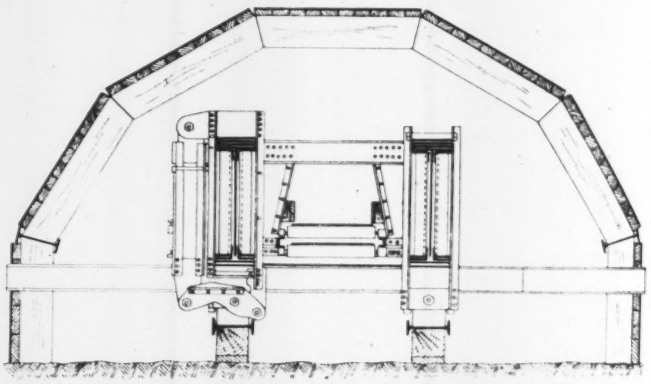


FIG. 12 SECTION OF LEWIS TRAVELING CANTILEVER GIRDER, SHOWING BELT CONVEYOR FOR REMOVING MUCK FROM HEADING

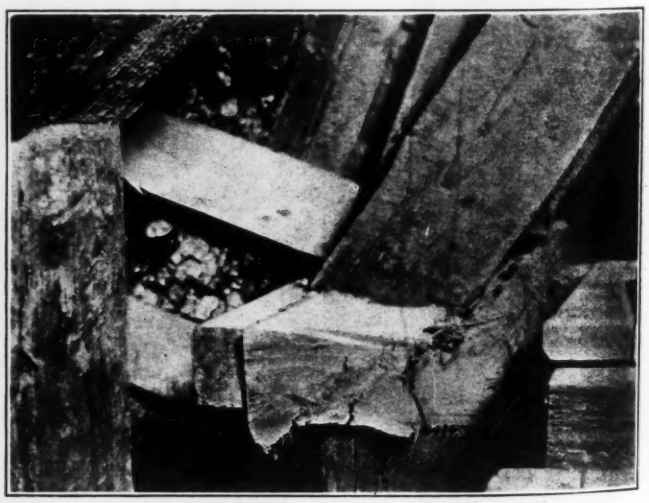


FIG. 13 CRUSHING OF WALL PLATES UNDER EXTREME PRESSURE, RESULTING IN THROWING TIMBERS OUT OF LINE

In excavating the bench, raker posts (Fig. 10) were at first employed, but later this system of supporting the wall plates which carry the arches was superseded by the Lewis cantilever (Fig. 11). In this system two 60-ft. steel beams rest for two-thirds of their length on the bench, and the portion projecting over the part to be excavated carries heavy cross-arms which support the wall plates and

hold the arch in position until the bench can be completely excavated and the posts placed in position, after which the cross-arms are retracted and the cantilever moved forward eighteen or twenty feet and the process repeated.

Toward the close of the work, when it became desirable to bring the completed tunnel closer to the point where the top heading had been enlarged to the full width of the arch, a belt conveyor was run through the center of the cantilever (Fig. 12) and the muck, taken out during the enlargement of the heading to full size, was sent out through the cantilever and dropped on the bench muck pile. This lessened the amount of muck to be sent out through the pioneer tunnel, which is single-track and when the haul exceeded two miles became greatly congested. The belt conveyor running through the cantilever was electrically driven and could be reversed so that timber and tools could be sent in on it.

FIG. 14 STABILITY OF SET DESTROYED THROUGH ROTATION AND CRUSHING OF WALL PLATES DUE TO UNEQUAL PRESSURE ON POST AND ARCH

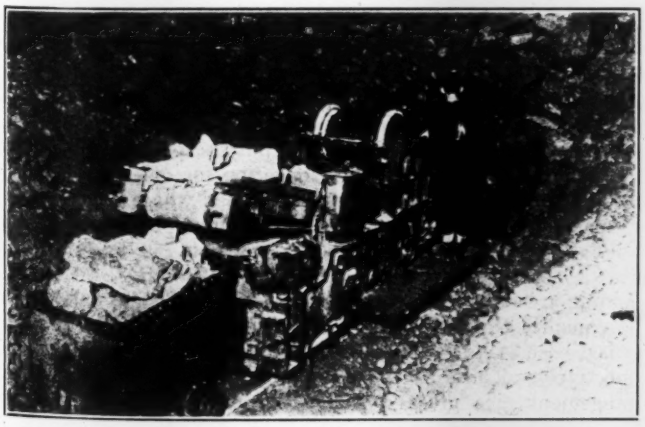


FIG. 16 SHOVEL REMOVING BROKEN ROCK FROM FACE

Near the center of the mountain, when the pressures became greater, it was found that when the stresses on the arch and posts were nearly equal, the 12 × 12-in. wall plates would crush and throw the timbers out of line (Fig. 13). Where the pressures on the post and arch were unequal, the wall plates would rotate as well as crush, thereby destroying the stability of the set (Fig. 14). To obviate this difficulty, the author introduced the use of an I-beam wall plate (Fig. 15), which like most successful inventions immediately developed collateral advantages. As the post and arch are only separated by the web of the I-beam, rotation and crushing are impossible, and at the same time the flanges of the I-beam hold both the arch sets and posts in their relative positions during both construction and maintenance.

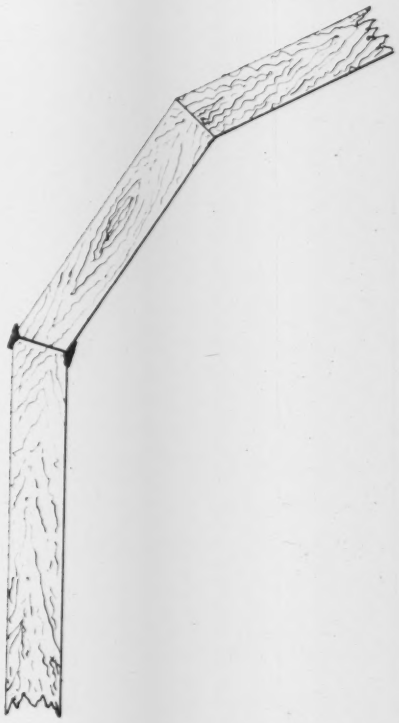


FIG. 15 I-BEAM WALL PLATE DEVISED BY AUTHOR TO OBVIATE DIFFICULTY ILLUSTRATED IN FIG. 14

EXPEDITIOUS DRILLING PROCEDURE DEVELOPED

When the broken rock at the face—or "muck" as it is usually called—was loaded into the cars by hand, the customary method of operation was to level off the top of the muck pile and have the machine men commence operations by erecting the drills on a cross-bar—and they were generally able to drill the upper holes before the shovelers began to dig the ground out from under their feet. The shovels now used in the tunnel (Fig. 16) will usually clean up the muck from a round of shots in from two to two and a half hours, and as the shortened period renders it inadvisable to attempt drilling on the top of the muck pile, the face is therefore cleaned up before drilling commences. It has been found both expeditious and economical to lay the rails up to the face as soon as the mucking is completed, and the four rock drills used in the heading are now mounted on a heavy carriage (Fig. 17) which can be run directly up to the face. These drills are always kept on the carriage

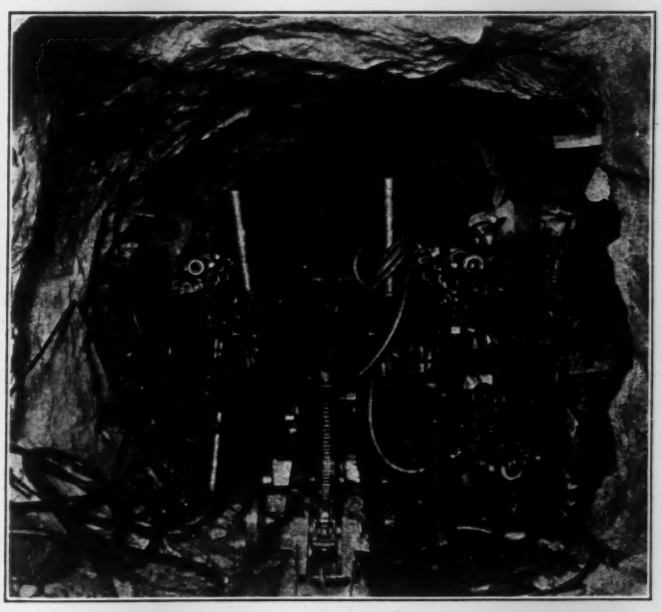


FIG. 17 FOUR ROCK DRILLS MOUNTED ON HEAVY CARRIAGE WHICH CAN BE RUN DIRECTLY UP TO FACE

and their air and water pipes connected to a manifold on the car, so that to begin drilling it is only necessary to connect the main compressed-air and water pipes with the manifold and run out the jackscrews to hold the car in position, operations which usually take from fifteen to eighteen minutes. Under the systems formerly employed the drills and the columns had to be carried back from the face by the men, far enough to be safe from flying rock, and in setting them up again they of course had to be brought back in the same manner, and by the time the columns were set up and the drills in place ready to run, the men were nearly tired out. Under the new system they begin drilling perfectly fresh, and of course are able to work much more efficiently, a condition clearly proved by the reduced amount of drill repairs.

Drilling, Loading, and Firing Synchronized with Mucking and Bringing Rails up to Face

As the railroad heading and the pioneer tunnel are carried forward at approximately the same rate of progress, it has been found desirable to synchronize the operations of drilling, loading, and firing with those of mucking and bringing the rails up to the face. Under this system, when the drillers are at work in the face of the pioneer tunnel the muckers are cleaning up the face of the railway heading, and as both operations are timed to be completed simultaneously, the machine men run their drill carriage and the muckers their loading machine back to the nearest cross-cut and change places. Under this system, even in the hardest rock, the machine men can readily drill, load, and fire two rounds in an eight-hour shift, one in each heading. Where conditions are favorable, eight rounds are often drilled in twenty-four hours.

Electric power for both portals is supplied from the Boulder Canyon hydroelectric plant of the Public Service Company. From the power plant to the East Portal the distance is twenty-two miles; the voltage is 44,000. Power for the West Portal is taken from the East Portal over a seven-mile temporary line, which crosses the Continental Divide at an elevation of 12,000 ft. and will be taken down when the tunnel is completed.

Miscellaneous Equipment

Both portals have well-equipped blacksmith and machine shops, also charging stations for the storage-battery locomotives.

In driving the headings, drifters are used; in the radial drilling from the center heading, stopers are generally used on the upper holes, while jackhammers are sometimes used in connection with the other drills on the bench.

The rock encountered in the workings from the East Portal was generally hard and self-supporting, consequently greater speed was obtained there than in the workings from the West Portal where the rock was crushed and required timbering. As a consequence the headings, instead of meeting at the apex as was intended, were thousands of feet apart when the east headings reached that point and it was necessary to continue them down hill on a grade of eight-tenths of one per cent. Owing to the natural depravity of inanimate things, a heavy flow of water, amounting at times to 3500 gal. per min., was encountered in these down-grade headings, which greatly reduced the rate of progress and necessitated the employment of an expensive electric pumping equipment consisting of three centrifugal pumps, one 2000-gal., one 1200-gal., and one 1000-gal. As the lift was slight, these pumps were easily operated, but, unfortunately, once during a severe storm a break occurred in the electric line and the pumps were submerged before power-line repairs could be completed.

Drill sharpeners are used at both portals and give excellent satisfaction, but their full benefit was not reached, and the oil forging and tempering furnaces should have been equipped with pyrometers so that correct temperatures could always be maintained. No matter how skillful a blacksmith may be, the apparent temperature of steel is greatly modified by changes from sunlight to shadow and from day to night. As a consequence, breakage of steel has been abnormally high, ranging from 2.2 to 4 per cent, and at one time for a few days, owing to an unnoticed defect in one of the sharpener dollies, breakages ran up to 15 per cent.

The consulting and construction engineers have unanimously recommended that all trains be hauled through the tunnel by electric locomotives, thus obviating the necessity for a ventilating plant and doing away with fire risk, which in the case of a six-mile timber-lined tunnel is unusually great.

Unfortunately, all connection of the engineers with the tunnel ceases on its completion, and it is understood that the Denver & Salt Lake Railway will not consent to electrification but will insist on operating through the tunnel with steam locomotives and attempt to clear out the gases by artificial ventilation.

The contract for the tunnels was let on September 20, 1923, and the pioneer tunnel was holed through February 18, 1927, the final blast being fired by President Coolidge pressing a button in Washington. The railroad tunnel headings met on July 13, and today (October 1, 1927) there remains 682 ft. of uncompleted bench, which at the present rate of progress should be finished on or before November 1. After this will come ballasting and track laying, which should be completed in time so that railway trains may pass through the tunnel before the end of 1927.

Determining the Proportional Limit of Steel

THE apparatus most frequently used in Sweden to determine the proportional limit of steel is the Martens' mirror extensometer. It is not, however, the author's intention at this time to describe or discuss the apparatus itself but instead to give his experience in preparing and arranging the test piece and extensometer and his suggestions as to where to place the proportional limit when the test is completed and the record ready.

When the proportional limit is to be determined, two opposite lines of the test piece are used for measuring the elongations. By this method it is most frequently found that the corresponding values from these lines are different and that the difference will increase during the whole test. This difference is most pronounced if the testing machine has four pulling screws and less pronounced if only one screw or a plunger is used. The cause of the error is due to the fact that the machine does not pull exactly through the center line of the test piece. It has been the author's experience that it is impossible to get an ideal machine for this purpose.

In order to reduce the error as much as possible, the author, after some experiments, developed the following arrangement. Instead of clamping the test piece directly in the moving head of the machine it is screwed into two small cylinders of hardened steel. The cylinders are threaded on both ends. On the opposite end to that of the test piece is screwed a steel rod which is fitted with its other end into the clamp of the machine. By this arrangement is obtained, using the ordinary test length, a much longer "test piece" built up from five different parts. The screws do not fit the threads tightly and thus they will allow a little movement for alignment.

The usual way to decide where to put the proportional limit is to calculate the average of the elongation for one step in the increase of the load and to determine the load where the elongation for one step is more than 10 per cent higher than this average value. This gives for the old arrangement 750 kg. (1650 lb.) and for the new arrangement 900 kg. (1980 lb.). The corresponding areas for the two test pieces are 0.043 and 0.044 sq. in. Consequently the proportional limit is in the first case 27 and in the last case 31 kg. per sq. mm. (38,400 and 44,100 lb. per sq. in.), respectively. The difference is about 13 per cent. The poorest arrangement also gives a slightly lower modulus of elasticity, 29,600,000 in comparison with 29,700,000 for the better one.

The method mentioned above for the determination of the location of the proportional limit very often gives, in the author's opinion, wrong results. This occurs especially when the elongations gradually increase for each step. In order to correct these difficulties, the author has developed the following method which has given good results for uniformity. The elongation of the specimen for one load increment is calculated on the basis of a modulus of elasticity of 28,400,000.

If the proportional limit is not obvious from the test data, it may be considered reached as soon as the observed increment in elongation exceeds the calculated. The method will help to give much more uniformity in determining the proportional limit than the other method.—Bengt Kjerrman in Transactions of the American Society for Steel Treating, July, 1927, p. 41.

Quenching: A Practical Study on Rapid Cooling

Common Methods of Quenching—Speed of Plunging—Influence of Direction of Plunging on Distortion Produced—Flat-Plate Plunging Experiments—Solid and Hollow Cylinders Plunged Vertically, Etc.

By PERCY J. HALER,[1] LEYTON, ESSEX, ENGLAND

THERE are many factors which influence the rate of cooling, and the following are of great importance: The mass and shape of the object cooled, the composition and temperature of the quenching medium, the velocity at which the object travels, and the direction in which the quenched object is plunged.

It is still a debatable point as to which liquid gives the most rapid quench and Table 1 shows very divergent views, largely owing to the methods of quenching.

TABLE 1 RELATIVE VALUES OF QUENCHING MEDIUMS

Speed in seconds	Quenching medium	Order of merit	Quenching medium
1.5	Mercury	1	Water spray
2.0	Water-pressure spray	2	Water at 20 deg. cent.
2.2	Rain water	3	Salt water
2.5	Hard, brine, and sea water	4	10 per cent sulphuric acid
3.0	Kerosene	5	Water at 50 deg. cent.
3.2	Light mineral oil	6	Mercury
3.5	Fresh fish oil	7	Linseed oil
3.6	Lard and old used fish oil	8	Water at 100 deg. cent.
3.9	Boiled linseed oil	9	Lead
3.9	Raw linseed oil	10	
(From Steel Thermal Treatment, by Urquhart.)		(Le Chatelier's experiments as plotted in Brearley's Heat Treatment of Tool Steel.)	

It will be noticed that Le Chatelier places water spray first and mercury sixth on the list, but it must be remembered that these results were obtained in two different ways.

Urquhart carried out practical tests on 0.9 per cent carbon steels ½ in. × ¼ in. in section, heated to 778 deg. cent. over a length of 2 in. and then plunged into the quenching medium. In this case the rate of cooling at about 720 deg. cent. was measured. Le Chatelier heated small cylinders of steel into which a thermocouple was placed and then observed the relative time required to cool from 700 to 100 deg. cent.[2]

Benedicks conducted similar experiments where the specimen was carried in a circular arc through the water. According to him, the cooling property of a liquid is chiefly dependent on a high latent heat, the specific heat, conductivity, and viscosity being of secondary importance; but these views are hardly in accordance with those of practical workmen, and were not obtained by taking into account the usual rate of motion of the quenched object.

Common Methods of Quenching

Among the more common methods of quenching the following can be considered:

Hand Quenching, where the object is held by the workman, usually by tongs, and is plunged into water with as great a velocity as possible.

Gravity Quenching, where the object is released just as it meets the surface of the water and falls to the bottom of the tank.

Dump Quenching, where the objects are released in a mass from the furnace and travel haphazardly through the quenching medium.

Spray Quenching, in which specially designed hardening machines, work with water under a minimum pressure of 40 to 50 lb. and a maximum temperature of 15 deg. cent.

There are also a number of other methods, but a great deal of hardened work is quenched by one of the first three mentioned.

Speed of Plunging

It is difficult to get any reliable information as to the speed with which the object travels through the water, and experimenters do not refer to this.

In hand quenching there is a vigorous lunge, the speed toward the end of the stroke being limited by the tendency of the muscles to contract. If the tank is deep the movement is continued by bending the back, and at the end the upward stroke commences.

The author had a number of tests carried out to determine this. A vibrating reed and an inked brush were used to mark a piece of paper fixed to a block on rollers which was pushed vigorously, starting in each case from rest. The average velocity varied with the individual, but the highest obtained was 6 ft. per sec., for 20 in.; other results gave 5 ft., 3.96 ft., and 3.58 ft. per sec. and retardation was very marked with certain individuals. Six feet per second would give a drastic quench.

In gravity quenching the object is released from the tongs just over the surface of the water, enters with no initial velocity, and at the end of about 2 ft. will have a velocity under 3 ft. per sec.

In the first case there is retardation of the specimen, and in the gravity quench, acceleration.

Dump quenching is the most barbarous method of all, and is one that few up-to-date firms would care to adopt. No two pieces are cooled at the same rate, and pieces still uncooled will lie at the bottom of the tank, affecting each other in an indeterminate way and tending to make up-to-date equipment useless.

The workman allows the material to fall through the water by gravity with some initial velocity, generally in the wrong direction (see Metallurgy of Steel, Harbord and Hall, vol. 1, p. 249).

It will thus be seen that practically all experiments and most hardening operations are carried out with velocity of entry into the quenching medium varying from a maximum of 6 ft. per sec. to 0 ft. per sec. and that consequently there is room for research.

Ayres[3] points out that the distortion bears some definite relation to the quenching temperature consequent upon the actual shock received, and it appears to him that in many cases the actual conditions of quenching are not so carefully studied as the actual condition of releasing an article to be quenched.

Usually the quenching tank is not deep enough, and in hand, gravity, and dump quenching the work at a high temperature is left lying on the bottom or on a wire shelf to cool under the worst conditions.

Reference might be made to one or two recent attempts to regulate the velocity of quenching apart from spray quenching.

In a French rolling mill rail steel of 0.5 per cent carbon content is manufactured by passing the rail directly from the rolling mill at the finishing temperature to a trough of hot water, of sufficient length. It passes through the trough at such a speed as will secure quenching at the proper rate through the critical temperature, then passing to the cooling tanks in the ordinary way.[4]

The heat treatment in the S.A.E. Specifications for carbon steel when used for gears of heavy section is as follows:

Normalize at 1650 to 1750 deg. fahr.
Carburize at 1650 to 1700 deg. fahr.
Cool in box
Reheat to 1600 to 1650 deg. fahr.
Quench in water at 110 deg. fahr.
Reheat to 1400 to 1450 deg. fahr.
Quench in water at 110 deg. fahr.
Draw at 250 to 500 deg. fahr.

It is probable that the quenching proviso of such a specification for heat treatment will ultimately be altered to read: "Quench in water at 110 deg. fahr. at a velocity of x ft. per sec."

Influence of Direction of Plunging on Distortion Produced

In studying Lineham's paper dealing with the hardening of screw gages with the least distortion in pitch,[5] the author was

[1] Principal, Technical College, Leyton. Assoc-Mem. Institution of Mechanical Engineers; Mem. A.S.M.E.

[2] *Revue de Métallurgie*, September, 1904.

[3] In discussion of a paper on the hardening of screw gages, by W. Lineham, in Proc. Inst.M.E., June, 1920.

[4] Cecil J. Allen in *Railway Engineer*, vol. 46, no. 546, July, 1925, pp. 221–226.

[5] Proc. Inst.M.E., April, 1920, p. 451.

struck with the variable results obtained; further, he had also learned from practical experience that it was possible to get widely different results under apparently the same conditions. After repeated failure it was found that the quenching bath was responsible for these variations, and the following tests are selected to illustrate the influence of the direction of plunging on the distortion produced.

A number of specimens were cut from the same mild-steel bar, were turned and ground to 0.9 in. outside diameter, drilled through the center and the hole reamed to $^3/_8$ in. The pieces were of varying length and received the same heat treatment, being carburized at 850 deg. cent. for three hours in eternite, allowed to cool, and then heated to 750 deg. cent. The quenching velocity was approximately 6 ft. per sec.

Figs. 1, 2, 3, and 4 show the alterations in length, diameter,

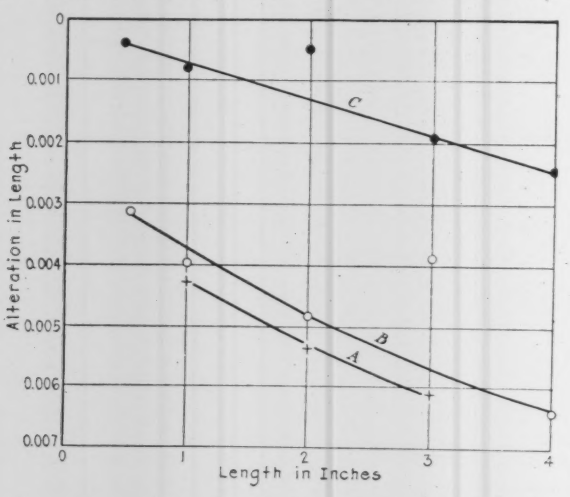


FIG. 1 ALTERATIONS IN LENGTH OF QUENCHED CYLINDRICAL SPECIMENS

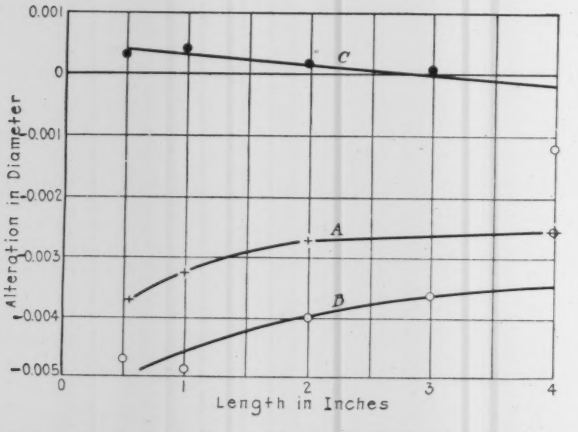


FIG. 2 ALTERATIONS IN DIAMETER OF QUENCHED CYLINDRICAL SPECIMENS

volume, and density. Curves A in each case record results obtained when the specimens were plunged horizontally. Curves B are for specimens plunged horizontally and swished vigorously, while curves C are taken from vertical plunging.

In studying these results and the original data the following facts emerge: In vertical plunging the entry end is always found to have become larger than the original diameter (0.9003 in.), and the increase or decrease in diameter varies as follows from end to end:

Length, in.	Final diameter of last end to enter water, in.	Middle, diam., in.	Diameter of entry end, in.
0.525	0.8997	0.9001	0.9018
	0.8996	0.9004	0.9017
1.0157	0.9002	0.9013	0.9027
	0.9008	0.9020	0.9028
2.0006	0.8994	0.9007	0.9020
	0.9008	0.9002	0.9030

In horizontal plunging the circumference shrinks as follows:

0.525	0.8953	0.8950	0.8965
1.0193	0.8960	0.8950	0.8952
1.0193	0.8965	0.8953	0.8950

FLAT-PLATE PLUNGING EXPERIMENTS

Another test was that of the dowel plate shown in Fig. 5, which was cased for three hours at 850 deg. cent. and then quenched at 750 deg. cent. by plunging it into water with its wide surface at

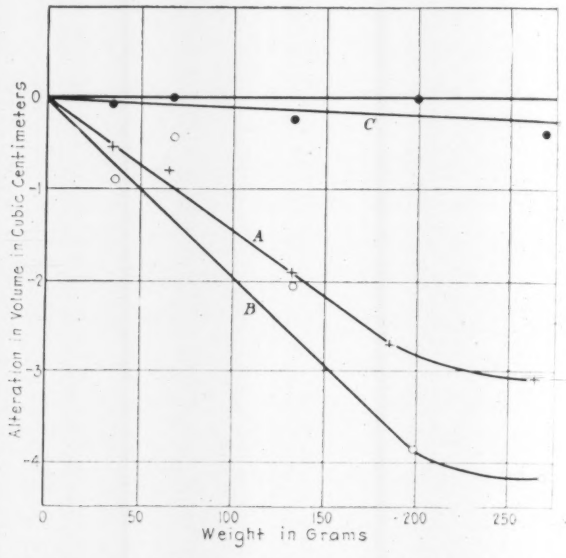


FIG. 3 ALTERATIONS IN VOLUME OF QUENCHED CYLINDRICAL SPECIMENS

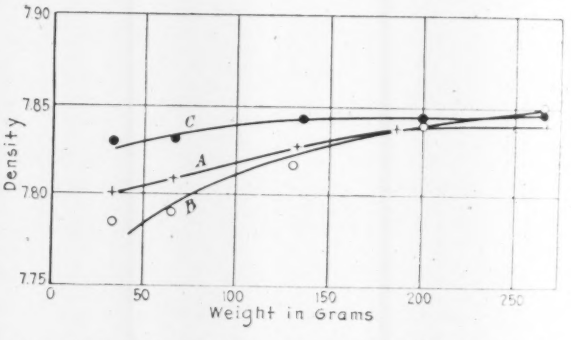


FIG. 4 ALTERATIONS IN DENSITY OF QUENCHED CYLINDRICAL SPECIMENS

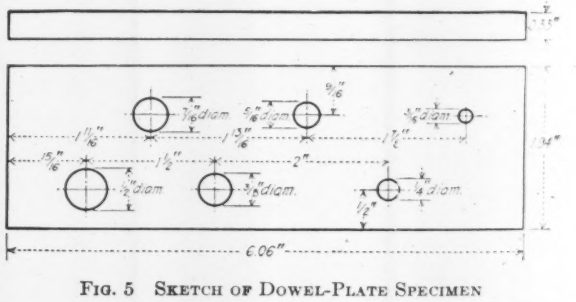


FIG. 5 SKETCH OF DOWEL-PLATE SPECIMEN

right angles to the surface of the water. The following average alterations in dimensions took place:

Length change	+0.0016 in.
Width change	+0.0014 in.
Thickness change	+0.0037 in.

A second plate was then quenched by plunging into water with its wide surface parallel to the surface of the water. This is not a method that would be adopted practically, and the surface was rounded in the direction of the length but not in that of the width. The following average alterations in dimensions took place:

	Vertical plunging	Horizontal plunging
Length change	+0.0016 in.	−0.0017 in. (not reliable)
Width change	+0.0014 in.	−0.0089 in.
Thickness change	+0.0037 in.	+0.00235 in.

Some important deductions may be made from those tests: It can be shown that if a cylindrical object is plunged horizontally

the diameter shrinks, and under certain conditions if vertically plunged, tends to increase in diameter.

The quenching deformations are produced in the initial period; modification continues, augmented by the speed of cooling, during cooling, while the resultant internal stresses must depend on the quenching deformations. "The growth of the speed of cooling

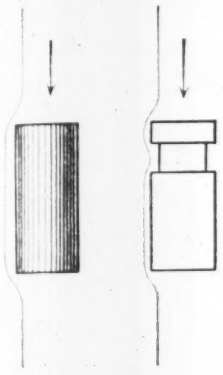


FIG. 6 SHOWING ONE STREAMLINE FOR CYLINDERS IN POSITION OBTAINING FOR VERTICAL QUENCHING

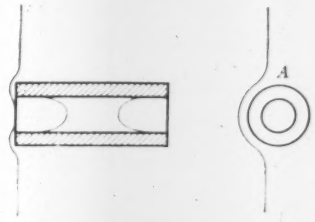


FIG. 7 IN QUENCHING HEATED SPECIMEN THE TWO PISTONS OF HOT WATER PRECEDED BY STEAM TEND TO REDUCTION OF DIAMETER AT CENTER

(If specimen sinks at the rate of more than 1 ft. per sec., turbulent flow takes place at side *A* and steam accumulates at this point first.)

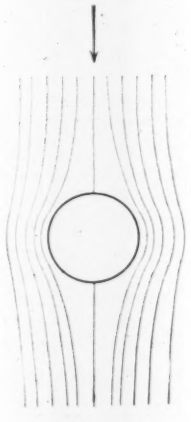


Fig. 8

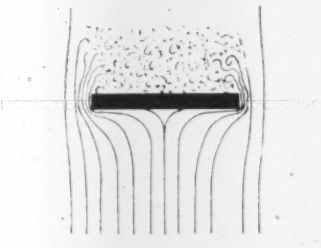


Fig. 9

FIG. 8 STREAMLINES AROUND INFINITELY LONG CYLINDER LYING IN WATER WITH AXIS HORIZONTAL

FIG. 9 STREAMLINES AROUND THIN DISK BEING PLUNGED THROUGH STILL QUENCHING MEDIUM

augments the alteration of volume as we can verify by comparison with the same diameter, comparing quenching by sprinkling and by immersion."[6]

SOLID CYLINDERS PLUNGED VERTICALLY

In the vertical plunging of solid cylinders the deformation brought about in the initial period is a swelling of the rim, which causes at a later period a local thermal stress, and its effect is sometimes seen when a small ring separates from the rest of the cylinder. In hardening milling cutters this is gotten rid of by adding a blank of the same diameter to take the first quenching shock.

It might be thought that as soon as the red-hot surface touched the water that there would be an instant generation of steam, but there was not.

This belief in the spontaneous generation of steam prevails especially with regard to boiler explosions which have taken place owing to a failure of the feedwater supply, which has ultimately allowed the boiler crown to get red hot.[7] These tests, however, disproved this idea.

It is difficult to discover the conditions for cooling, but the hardened ring mentioned above gives a clue. It is obvious that after the specimen has transmitted to the water sufficient heat to bring it up to or past the boiling point, it can absorb no more, and that the water which has previously been wetting the specimen will turn into steam. The general conception is that the cooling goes on equally on all the wetted surfaces, and such an idea is necessary on any mathematical theory.

[6] Portevin, Comptes Rendus, vol. 169 (1919), p. 955.

[7] See tests carried out by the Manchester Steam Users' Union and reported in *Power House*, vol. 15, no. 24, Dec. 20, 1922.

According to McCance, "on immersing a uniformly heated bar in water at 0 deg. cent., the first thin layers of water in contact with the surface of the bar are rapidly heated to their boiling point and steam is formed, which, expanding outward, causes a fresh layer to come in contact with the surface, the process being repeated. The surface of the bar alternates between 0 and 100 deg. cent. while the steam acts as a carrier of heat to the body of the liquid. This goes on until the supply of heat is insufficient to form steam, when the transference of heat to the cooling of the bar takes place by convection only."[8]

Further, a hypothesis dealt with by Fourier assumes that there is a sudden cooling of the surface to final temperature or presupposes a quenching with an infinitely rapid cooling medium; in fact, any mathematical theory must consider a uniform cooling of the surface.[9]

From a study of streamline motion it is easily realized that uniform cooling of the surface is not possible, and the problem has been attacked by allowing flowing water to pass various rectangular and cylindrical objects and studying the various streamlines. Similar forms have then been made in which the exterior is formed of fine high-resistance wire. Steady conditions were obtained with the cold form and the streamlines studied under normal conditions, then the current was switched on and they were studied under the new conditions.

Fig. 6 shows one streamline for cylinders in the same position as obtained in vertical quenching; with an infinitely long cylinder

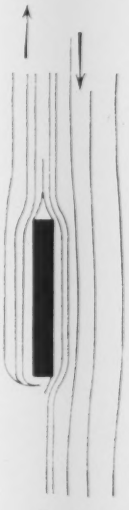


Fig. 10

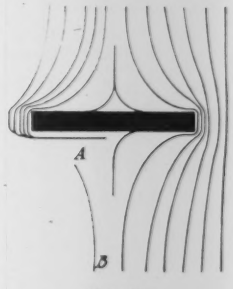


Fig. 11

FIG. 10 STREAMLINES AROUND THIN RECTANGULAR FORM

FIG. 11 STREAMLINES AROUND THIN RECTANGULAR FORM

lying in the water with its axis horizontal, the streamlines would theoretically be as shown in Fig. 8.[10] These figures show that the streamlines are totally different for the two cases, and it has already been shown that the distortion is different.

THIN CIRCULAR DISK

Another illustration might be taken: Supposing that a thin circular piece is being plunged through the still quenching medium, the streamlines will be as shown in Fig. 9; in the center the whole of the momentum will be converted into pressure energy, while toward the edges a greater part will be converted into velocity energy.

It has been proved that streamlines are the same when flow takes place past a fixed obstacle as when the obstacle moves at the same speed as the stationary fluid.[11] Further, the type of flow taken on the under side of the object depends on the velocity. If it is more than 30 cm. per sec. then there will be turbulent flow;

[8] McCance, A Contribution to the Theory of Hardening, Proc. Iron & Steel Inst., vol. 7, no. 5, 1914.

[9] Quenching, a Mathematical Study of Various Hypotheses of Rapid Cooling, *Physical Review*, vol. 20, Sept., 1922, p. 221.

[10] See also Reports and Memoranda No. 76, Advisory Committee on Aeronautics, or *Engineering*, July 9, 1926.

[11] Applications des lois de similitude a l'étude des phenomenes qui si produisent a l'aval d'un corps immergé dans un fluid visqueux en mouvement, M. Camichel, Correspondent de L'Institute Directeur de l'Institut Electrotechnique de Toulouse, in a paper before the Société Francaise de Navigation Aerienne, July 1, 1925.

30 cm. per sec. is roughly 1 ft. per sec., and it has been shown that it is possible to get a quenching velocity of 6 ft. per sec.

If the velocity is diminished to under 2 cm. per sec. or 0.0656 ft. per sec., the surfaces of discontinuity disappear and are succeeded by a central turbulent ring together with two vortices.

When the thin rectangular form is stationary and there is a slow velocity of flow past the form, the streamlines are as shown on the right of Figs. 10 and 11, but immediately the form is heated the lines reverse in direction as shown on the left of the same figures. The heat passes to the water on the underside by conduction and the water is only heated for a very short distance. This is illustrated by the original streamline being cut as at AB in Fig. 11 and remaining persistent for some time.

It will thus be seen that as soon as the current is switched on the streamlines change direction, and the hotter the form the more they tend to become sinuous.

In actual plunging the turbulent flow set up with velocities of over 1 ft. per sec. and shown in Fig. 9 will be intensified by the red-hot metal, but as soon as the surface has dropped in temperature it will tend to become as shown on the right of Fig. 11.

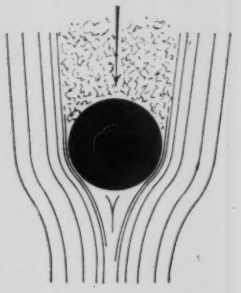


FIG. 12 STREAMLINE FLOW FOR AN INFINITELY LONG CYLINDER SINKING WITH A VELOCITY OF OVER 1 FT. PER SEC. IN A STATIONARY FLUID

(If red hot the under side will heat a band of water not more than 0.1 in. in thickness, and the heat will add to the turbulence of the top side. When reversal of direction takes place, if the specimen is still red hot there will be a turbulent flow on both sides. Usually the surface is cooled and gives streamline flow on the top side.)

STREAMLINES AROUND A STATIONARY CYLINDER

Take again the case of the streamlines around a stationary cylinder (Fig. 8); if the velocity is over 1 ft. per sec., turbulent flow will take place on the downstream side of the body, and will be spread over more than half of the underside of the circumference. With drastic quenching and a stationary liquid this will be on the top side (Fig. 12). It therefore follows that steam will be more freely generated on this side, keeping one part of the circumference hotter than the other and allowing greater shrinkage of the high-carbon-steel shell. Take the following tests:

Case-Hardened Cylinders Plunged with Horizontal Axis Parallel to Plane of Water:

Avg. diam.	Avg. length	Change of diam.	Change of length
0.8973	0.89927	−0.0001	0.0009
0.8972	1.8955	−0.00023	−0.00063
0.89723	2.89932	−0.00025	−0.00205

(Note that length practically equals diameter, giving more surface for a given volume.)

Case-Hardened Cylinders Plunged with Horizontal Axis at Right Angles to Plane of Water:

0.9002	0.89972	−0.00033	+0.0006
0.9000	1.8974	+0.00033	+0.00117
0.9000	2.89665	+0.00016	+0.00122

(See above note.)

With drastic vertical quenching, when the length is more than three diameters long, eddy formation takes place around the edges of the base which first meets the stream, followed by streamline and eddying water in the wake. The stream in this case has more chance of being swept away, hence there will be rapid cooling of the shell.

HOLLOW CYLINDER PLUNGED VERTICALLY

Another case which is obvious is that of a hollow cylinder plunged vertically, that is, with the plane of the hole parallel to the plane of the surface of the water. It is known that rings above 3 in. in diameter open out, becoming larger, and it is therefore necessary for the lathe operator to make the ring smaller in diameter to provide for a grinding allowance.[12]

The maximum and minimum allowances for rings up to 8 in. in diameter may be found from the following rules:

$$\pm \text{ Maximum allowance to be added to standard size} = 0.05 \log D + 0.015$$

$$\pm \text{ Minimum allowance to be added to standard size} = 0.04 \log D + 0.01$$

where D = internal diameter of the ring.

It will be noted that with small rings no allowance is necessary, the ring coming in and providing its own grinding allowance, the first quenching for the inside being hot water preceded by steam.

For an 8-in. ring the above rules give:

$$\text{Maximum allowance} = 0.05 \log 8 + 0.015 = 0.060 \text{ in.}$$
$$\text{Minimum allowance} = 0.04 \log 8 + 0.01 = 0.046 \text{ in.}$$

That is, the lathe operator must turn between the limits 7.96 in. and 7.954 in. in order that outward distortion and grinding may be provided for.

From a series of experiments carried out by the author on 8-in. and 5-in. rings carburized at 900 deg. and quenched at 850 deg. cent., and by Blue (*American Machinist*, Aug. 12, 1922) on $\frac{1}{2}$-in., 1-in., $1\frac{1}{2}$-in., and 2-in. rings carburized at 926 deg. cent., reheated to 888 deg., quenched in oil, tempered at 792 deg. cent., and quenched in water, the following rule has been deduced:

$$\text{Distortion} = -0.00037D^2 + 0.0068D - 0.0163$$

The actual distortion on an 8-in. ring from this rule is 0.0145 in. It must of course be remembered that the higher the quenching temperature, the greater the distortion.[12]

The distortion of small rings is due again to the difference in temperature of the quenching water on the inside and outside of the cylinder and the resulting thermal stresses produced.

In quenching screw gages, they are plunged vertically at comparatively slow velocities. The streamlines which run near to the crest of the thread of a screw are deflected slightly inward toward the core and then outward to the next full diameter, but this can be observed experimentally only on a screw with a big pitch. The full and effective diameter will be cooled first. The core will be shielded by hot water and steam and must cool more slowly, and shrink, owing to the heated mass of the body of the gage. The following results illustrate this point.[13]

Screw Gage, 20 Threads Whitworth

		Before hardening	After hardening	Change	Remarks
Full diam.	F	1.1491	1.1516	+0.0025	Entry end
	M	1.1492	1.1513	0.0021	
	B	1.1491	1.1518	0.0027	
Effective diam.	F	1.1176	1.1203	0.0027	Entry end
	M	1.1176	1.1191	0.0015	
	B	1.1175	1.1196	0.0021	
Core	F	1.0848	1.0874	0.0026	Entry end
	M	1.0848	1.0862	0.0014	
	B	1.0848	1.0862	0.0020	

Generally, in the tests given in this paper, shrinkage is only occasionally experienced in the core and depends on the pitch.

	Before hardening	After hardening	Change
Full diameter	1.3071, 1.3075	1.3077, 1.3079	+0.0006, +0.0004
	1.3075, 1.3070	1.3082, 1.3081	+0.0007, +0.0011
	1.3072, 1.3075	1.3085, 1.3081	+0.0013, +0.0006
Effective over needles	1.3250, 1.3255	1.326, 1.3264	+0.0010, +0.0009
	1.3235, 1.3235	1.3244, 1.3245	+0.0009, +0.0010
	1.3237, 1.3233	1.325, 1.3241	±0.0013, +0.0008
Core over pieces	1.5340, 1.5336	1.5335, 1.5336	+0.0005, 0.0000
	1.5339, 1.5340	1.5337, 1.5340	−0.0002, 0.0000
	1.5339, 1.5337	1.5341, 1.5339	+0.0002, +0.0002

As additional proof, a $\frac{3}{4}$-in. diameter cylinder 3 in. long was prepared and threaded the entire length with a U. S. standard thread, 10 per inch. The actual rate of center quenching calculated at the cooling velocity of 720 deg. cent. per sec. was 92 deg. cent. per sec. against 90 deg. for a similar plain cylinder.[14] The surface per unit volume of this threaded specimen and of an unthreaded cylinder of the same length and diameter were respectively 11.0 and 6.0.

The streamlines or the convection currents are the factors in quick cooling producing initial deformation. Spaces which allow warm water, steam, or air to accumulate must delay cooling. A series of tests were carried out by cutting a free screw thread on the outer surface of a calorimeter tube with the object of breaking up the flow of water and thus increasing the rate of heat transmission. In another series the tube surface was not so broken. Com-

[12] Haler, Predicting the Distortion of Heat-Treated Case-Hardened Rings, *Engineering*, Oct. 15, 1926, p. 470.

[13] Lineham, Proc. Inst.M.E., June, 1920.

[14] Initial Temperature and Mass Effects in Quenching, French and Klopsch, U. S. Bureau of Standards, August 25, 1925.

paring results, it was found that the rate of heat transfer is not appreciably altered, probably due to the bottom of the thread being filled with nearly stagnant water, which neutralizes the good effect produced by the water scrubbing hard over the tops of the thread.[15]

In a paper by K. Heindlhofer,[16] it is pointed out "that comparison of the experimental curves with solutions obtained mathematically bears out the fact that the hypothesis in which it is assumed that steam is formed at the boundary of the solid (Leidenfrost effect). That the water-steam surface remains parallel with the surface of the solid and that heat moves in the liquid by conduction alone is untenable after the first stages of quenching.

Neither is the hypothesis valid that steam is formed at the bordering of the solid, and that the surface water-steam remains parallel with the surface of the solid; heat is removed by convection only at a uniform rate.

This is explained by the fact that the thickness of the steam film grows rapidly, becomes unstable, and bubbling is set up.

From a study of the streamline effect in connection with the dimensional changes of a case-hardened specimen, it is most probable that there is a tendency for the steam to form in bands, along planes where the direction of flow is a minimum or where eddying is set up.

It is obvious that the casing of, say, 0.9 per cent carbon steel will tend—

a With almost instantaneous surface cooling to give an increase of volume.

b With slower surface cooling to give a decrease in volume.

c With a band of steam, say, on the longitudinal surface of a cylinder plunged as shown in Fig. 12, to give a decrease in volume.

In conclusion, it is evident that there has been little progress in many shops as far as quenching operations are concerned. A tank of some type with a means of keeping the water cool is looked upon as all that is necessary.

It is extremely likely that not only will spray cooling be provided, but also cooling with sprays of appropriate temperature or with jets of different types and temperatures.

Plant Location

Check Lists of Influencing Factors for Studies of Location and Site

By TYLER STEWART ROGERS,[1] NEW YORK, N. Y.

PLANT location from an engineering viewpoint may be construed as a very broad subject, if one is permitted the promise that it is an engineer's job to find the best location for any given manufacturing plant. As a matter of fact it is one of the secret regrets of the engineering profession that very few manufacturers consider that an engineer is of any value until the site has been chosen. In this respect at least, the realtor has the better of the engineer.

The problem of locating a new industrial plant divides itself logically in two parts: first is the selection of a location, and second is the selection of a site. The distinction should be noted. "Location" connotes a much broader territory than "site" and might be defined as a general region or district, whereas "site" should be used to connote only a specific piece of land of limited dimensions.

Studies to select a suitable location should cover the following ten subjects: (1) Climate, (2) natural resources, (3) power sources, (4) transportation of raw materials, (5) distribution of finished products, (6) labor characteristics and supply, (7) state and local labor and tax legislation, (8) cost of moving, (9) type of plant, and (10) local advantages.

The relative importance of these elements varies with every problem. The predominating element as well as the final choice can only be determined by studies which show the influence *on profits* of each of these items. It is therefore desirable to reduce all of the elements to a dollar basis as the first step in any careful study to find the best location for any given new plant.

Probably the majority of manufacturing executives who are faced with a problem of plant location arrive at their conclusions after a relatively cursory examination of various territories; guided and influenced in a large measure by their personal judgment and experience, and not infrequently by their personal preferences for some specific section. A thorough and expert analysis of all of the factors bearing on the location of any new plant may reveal advantages and economies inherent in some unconsidered region that would result in substantially increased profits extending over a period of many years. If the author could broadcast this message to reach plant executives he would stress just one matter. He would advise executives to challenge every opinion expressed with regard to any aspect of a new plant-location problem, and to question every statement until figures and facts that cannot be disputed are received.

[15] Jordan, Heat Transmission Between Fluids and Metals, Proc. Inst. M. E., November, 1909.

[16] See footnote 9.

[1] Consultant. Formerly N. Y. Manager, The Ballinger Company.

Presented at the First National Management Meeting, Rochester, N. Y., October 24 and 25, 1927, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Probably the best way to discuss the question of plant location is to develop something in the form of a check list of the factors which have an influence on this subject.

CLIMATE

Climate is either a very important factor or is no factor at all. It becomes important for certain special industries in which humidity or rainfall or extremes of temperature may facilitate the manufacturing process or may have a strong bearing upon the natural resources which constitute the raw materials involved. Certain textile processes are most successfully conducted in an atmosphere of relatively high average humidity. Certain printing processes, on the other hand, especially color work in large volume, are seriously hampered by variations in humidity due to the stretching or shrinkage of the paper stock and the consequent difficulty in making the various colors register properly when they are run through the presses on different days. However, the influence of climate is diminishing because it is now possible to produce artificially almost any desired degree of humidity or dryness of the air within a building. In fact, artificial humidity and temperature control is often vastly better than relying on prevailing climatic conditions. Other things being equal, the problem resolves itself into an analysis of the cost of such artificial weather making as compared with the results of locating the plant in a territory offering the most favorable natural conditions.

NATURAL RESOURCES

Natural resources affect only certain industries. They become a factor when an extremely large supply of water is required or where natural gas, minerals, fuels, and other raw materials of like nature must be available in close proximity to the plant. The question here is whether it is more economical to locate near the natural sources, to transport raw materials to a more desirable manufacturing center, or to procure an adequate water supply through artesian wells or other semi-artificial sources, as the case may be.

An illustration of this factor is to be found in the surveys recently undertaken by the National Biscuit Company in connection with the location of a new eastern paper-board mill and printing plant. The large volume of water needed in the paper-manufacturing process and the necessity for disposing of the waste water in a river large enough to dilute the effluent below the pollution point soon limited the available locations to sites on the Hudson, Delaware, and one or two other large eastern rivers. It was quickly found that artesian wells alone would not solve the problem, for a satisfactory outfall was as important a matter as a sufficient water supply.

POWER

Certain industries require water power or electricity in quantities that are available only at certain places or that are only cheap enough to justify their use in certain locations. The cheap electricity available at Niagara has drawn to the surrounding regions many industries involving electrochemical and other electrical processes dependent for their commercial success upon electric power in unusual quantities at low rates. A number of other regions throughout the country are developing along similar lines due to their capacity to produce power suitable for such industries. The question here is a matter of comparative power costs. The development of new power sources, the growing network of superpower systems, and the cheapness of electricity for daytime industrial uses in certain cities that have their maximum loads for night lighting make this problem one of no simple solution. Philadelphia, for example, enjoys steam-generated electric power at rates formerly considered possible only through major hydroelectric developments.

TRANSPORTATION OF RAW MATERIALS

The fourth item, the transportation of raw materials, must be taken into consideration with the one following, the distribution of finished products. The cost of transportation of raw materials and the cost of distributing finished products must be balanced, one against the other, to find a locality which reduces the sum of these costs to the lowest possible point. The first step in studying the raw-materials situation is to determine freight and handling costs to typical centers where the plant might be located. The trial-and-error method is used. It should be noted that if the removal of an existing plant to a remote section seems a possible solution, then certain of the raw materials now obtained from nearby sources might be procured from totally different sources nearer to the proposed site. The cost figures should make allowance for savings in handling costs by approved methods in the new and presumably ideal plant. The studies should include not only rates but time in transit of water, rail, and motor-truck haulage to see which method of transportation offers the maximum advantages. Note should be taken of the fact that there may be extra overhead if large reserves of stock must be kept on hand when the plant is located remote from the source of its raw materials. These reserves should be sufficient to prevent the plant from being shut down when the transportation systems are tied up due to weather conditions, strikes, or other causes. The cost sheet should reflect the interest on the capital tied up in such excess reserves. These studies often prove the obvious answer to be wrong. For example, chrome ore is brought from New Zealand to Jersey City for refining. A list of the raw materials imported by American manufacturers reveals many cases of economical long hauls to desirable production centers.

DISTRIBUTION OF FINISHED PRODUCTS

Distribution of finished products is very definitely related to the last item but is approached through somewhat different channels. Often it is desirable to chart on maps the principal centers to which the products go, indicating graphically or otherwise the relative volume to each center. When an industry distributes its products through wholesalers or jobbers it is relatively easy to define the major centers of absorption of the product and to find their relative importance. When the product is sold direct to the consumer without intermediate warehousing it is too great a task to establish the distribution precisely, and the problem resolves itself into estimating the average shipment per year to certain cities taken as typical of larger regions. With these data as to proportionate distribution on hand, transportation studies should be made to determine the location for the plant which would result in the lowest transportation costs chargeable to distribution of finished products, bearing in mind, however, that the time element is often of more importance than the actual cost of transportation. The trial-and-error method is used in this work generally, the first location study being that which is found to be most desirable from the raw-materials point of view. Then for comparison other cities or general centers are taken in various sections of the country to see whether the distribution costs would be less at any other point. Eventually the location should be found which has the lowest distribution cost consistent with a reasonable time schedule for delivery of products from plant to buyer.

LABOR

Taken in a general way, sometimes labor has a greater bearing on plant location than any of the factors previously discussed, as for instance when a definite type of labor is needed. The native mountain labor in the South, wholly untrained until it comes to a plant, but capable of being trained for semi-skilled work, often is more desirable to a manufacturer than highly experienced labor in some of the other sections of the country where industries have been in existence for generations. This is due to the fact that often it is easier to train labor to perform a certain operation differing from those employed in other common industries than it is to break trained labor from its accustomed methods and teach it something new. The Pennsylvania Dutch region offers another distinct type of labor of great stability and similarly capable of being trained for semi-skilled work of a simple nature. The predominant nationality of a labor force has a bearing on its characteristics, and the prevalence of workmen of any desired nationality may be found in one section to such an extent as to make that the proper choice for locating the plant. Other industries must have highly skilled labor accustomed to precision work, and the cost of training raw labor in a new locality would be fatal to the success of such a company, which should establish itself in a section where employees can be had already experienced in similar manufacturing establishments.

General wage scales of course are of paramount importance to almost every industry, and it only takes a brief study to find that various sections of the country show marked variations in average wage scales. One client recently found that the removal of his plant from northern New Jersey to Baltimore, Md., would effect approximately 15 per cent reduction in his wage scale and still supply him with equally satisfactory labor. It should be borne in mind that the annual payroll in the average manufactory is often equivalent to or in excess of the actual value of the physical plant. It is hard to make up through other factors the effect of a ten or twenty per cent variation in wages.

Unionism has a bearing on plant location, some industries finding highly developed union control desirable provided the union management is willing to coöperate on a sound economic basis. Other industries have been seriously hampered in their work by disastrous conflicts with unions, and they may find it desirable to seek an open-shop locality. However, in the author's opinion, this element is of no permanent value, because the unions are entering territories where they have not heretofore made progress, and also unions long established in some of the older manufacturing centers have changed about from being obstructive to manufacturers to a point where they are actually advantageous. Unionism is a subject that the author will not attempt to enter into, but it must be realized that it is changing constantly and that its success is largely dependent upon the caliber of the union officials. This personnel changes from year to year. Union policies are also being modified, and those who are optimistic feel that ultimately a sound economic basis will be established in labor relations that will practically take this factor out of any problem of plant location.

Quantity of labor available is also one of the general factors, but in the author's opinion this is a factor influencing the more specific location of a plant in the great majority of plant-location problems. With modern means of transportation manufacturers today can draw upon large areas so that the quantity element in labor supply can be successfully overcome in almost every section of the country, except in some of the relative unsettled parts of the South and Southwest, as for instance, in the mining regions of Arizona and New Mexico. Even here the labor problem can be solved by housing often to greater advantage than by attempting to transport raw materials to major labor centers. In such cases a careful study of housing costs becomes an important element in the plant-location investigation.

When plant-location studies have narrowed the field to the choice between two or more tentative sites, the specific study of labor conditions may become as involved and as important as all of the foregoing matters put together. It may require investigation by an experienced employment manager of neighboring factories, an

intensive study of housing facilities, trends and growth of population, local transit facilities and schedules, and a host of other apparently small matters which taken in the aggregate make up the difference in desirability of one site over all the others.

State and Local Legislation

Closely associated with the labor problem as well as with other more general factors is the seventh item on the list, state and local legislation. State labor laws particularly may have a major bearing on the choice of the several states as to hours of labor, employment of females and minors, minimum wages, and the working environment. The provision of rest rooms, toilet facilities, protection against accidents, stairs, and other exits, and many other design features of industrial buildings are subject to regulation. When housing is contemplated, tenement-house laws become an influence. Fire protection may be influenced by state laws as well as by local ordinances.

Taxation is even more important and more variable as between the states. The forms of taxation imposed upon corporations have become so complex as to be a subject for determination by specialists in taxation and accountancy, whenever the choice of location lies between two or more states.

These matters, while not of a strictly engineering nature, must be given due weight in selecting plant locations. It should be noted, however, that such factors are of political origin and have no assurance of permanency in their effect upon specific locations.

Cost of Moving

The eighth item is cost of moving. When other elements show little influence upon the location of a plant, there being, however, a slight advantage apparent in the removal of the industry to a considerable distance, the cost of moving should be taken into consideration as it may be heavy enough to reduce the advantage of the remote location. When a distant move is contemplated the manufacturer must accept a considerable loss of labor with the attendant cost of breaking in green hands and building up a new and smooth-working organization. Generally it is necessary to pay the cost of moving the families of the key employees of a plant to the new site, and this, together with the actual cost of transporting and setting up a plant, may run into a considerable item. A limited move, as from one part of a city to another, generally means the loss of the minor employees, especially girls and boys who live at their homes and who have not become settled in their employment and can readily find other jobs without having to travel longer distances to and from their work.

Type of Plant

The selection of a one-story as compared with a multi-story building has an important effect upon the size of the property to be procured as well as upon the price that could be paid for the property without involving undue overhead expense. If the plant is one that creates a public nuisance through odors, smoke, or through fire or explosion hazards, the final site must be chosen in districts where such characteristics would not be objectionable to local authorities.

Local Advantages

The last item covers the whole subject of local advantages. Among the points to be considered that have not been covered above are such matters as community support for a new industry through tax exemption, free sites, free railroad sidings, and the adequacy of local utilities. For some years there was a great tendency on the part of too aggressive chamber of commerce secretaries to hold out rather extraordinary inducements to manufacturers to locate new plants within their territories. This sort of enterprise has proved to be a "double-edged" sword and is now considered unsatisfactory both from the point of view of the manufacturers as well as the chambers of commerce. Nevertheless the moral support and good-will of a community is a very desirable element in the final selection of a site, for such support can do wonders in smoothing out petty annoyances and difficulties with local authorities and making the path easy for getting a new plant into production.

Furthermore, consideration should be given to the adequacy of existing utilities such as water supply, fire protection, sewerage systems, passenger-transit facilities, roads, schools, playgrounds, and other public works. If certain necessary utilities are inadequate to meet the company's requirements it may be necessary in one community to pay for the improvements or extensions, while in another community the work would be cheerfully done without cost to the new industry.

Site Selection

The elements in the problem of actual site studies are (1) railroad siding and waterfront improvements, (2) size and orientation of property, (3) topography, (4) geology, (5) public utilities, (6) publicity value, and (7) the ultimate cost of improvements.

Railroad Siding and Waterfront

Railroad siding is often of first importance. The cost of the siding, of interlocking signals to protect the main-line tracks, of bridges and culverts if the siding must cross water courses or roads, and similar factors should all be taken into consideration. In one recent project the manufacturer purchased his site without checking the question of railroad siding and subsequently found that the freight track was separated from his property by four high-speed passenger tracks. It was almost impossible to induce the railroad to put in the necessary cross-over, and the cost of switches, interlocking signals, and other track work will exceed $50,000. If the property had been on the other side of the main-line tracks the siding could have been had for only a few thousand dollars' cost.

If the plant requires a waterfront site, studies should be made of the comparative cost of securing and maintaining adequate depth of water, and constructing piers and bulkheads. The selection of waterfront industrial sites is often such a complex problem as to warrant the attention of specialists.

Size and Orientation of Property

Next is the size, shape, and orientation of the property. Sufficient area should be purchased to provide room for expansion and to prevent the encroachment of neighboring structures from interfering with light and access. Many of the large plants are purchasing extra land for recreation areas and for the development of grounds in front of the building with planting and other ornamentation in order to give the plant the proper architectural setting, thereby increasing its attractiveness, resale value, and its effect upon the morale of its employees. The size of the grounds should also be such as to permit the building to be placed with proper orientation to points of the compass, especially if advantage is to be taken of north lighting in any considerable part of the plant.

Saw-tooth buildings particularly should be so arranged that their skylights face due north, and the building is less expensive if the saw teeth can be placed at right angles to the walls rather than in a diagonal position across the building. The latter can be done, however, and it is sometimes better than to discard a site which otherwise is satisfactory. Multi-story buildings also are very often best arranged if the long side can face the north. This enables departments doing fine or precise work and practically all inspection departments to enjoy the uniform lighting that comes from north-side-wall windows and minimizes the window area subject to the variation of direct sunlight from morning to night. Orientation becomes a factor in site selection when the lots under consideration are so limited in size as to require the building to be erected in a fixed position.

The shape of the property as well as its size often affects railroad-siding costs by limiting the track layout, and by forcing the use of short-radius curves. This occurs only when the plot is quite restricted in size.

Topography has an important effect upon the choice of site. Grades should be very carefully checked by instrument, because often an apparently level tract actually has a slope which would involve expensive foundation work or large waste areas in basements formed by propping up the main floor level to a suitable grade. In some instances, of course, a slope works out advantageously as, for example, in a warehouse recently completed in Philadelphia where the railroad siding comes in at the basement grade and the shipping platform, where trucks are loaded for local deliveries, is on the first-floor grade. This physical separation be-

tween receiving and shipping proved to be much more advantageous than would have been the case if both were done at the same point.

GEOLOGY OF SITE

No site should be purchased without first obtaining complete information as to subsoil conditions. Core borings should be taken at reasonable intervals over the property if there is the least suspicion that the soil at the level of the main footings will not bear a load of at least two to three tons per square foot. If the site is rocky, any outcropping above the main level of the building adds materially to cost of grading, although very often the stone removed can be used for foundation work and the rigid foundation resulting from a rocky site may prove advantageous. A plant in Long Island City was developed on a site of considerable length and not very great width. It was found that there was a rock ledge a few feet underground extending the entire length of the proposed main building, but when it came to adding a power house at the far end of the property, borings indicated that the rock sheared off in an underground precipice and it was necessary practically to float the power house as a separate unit from the main building and to use very long piles in its foundations. Nothing appeared on the surface of the property to indicate this extraordinary condition.

Drainage, of course, is also of great importance, and if the plant is located in a region subject to floods this factor requires very serious consideration. In some of the central western regions where the larger rivers have an annual variation in water level exceeding 30 ft. and flood stages sometimes as much as 54 ft. above mean low water, it is a serious matter to locate a plant where it cannot be affected by even the most extreme floods.

PUBLIC UTILITIES—PUBLICITY VALUE

Each site should be compared as to the availability of adequate water, gas, and electric supply systems, and proper sewage and drainage facilities. If these utilities arenot present, or are of insufficient capacity, the cost of extensions or of enlarging present capacities should be added to the cost of each site. Transportation facilities such as bus lines, car lines, and good roads for private automobile use should likewise be compared.

Publicity value is being recognized more and more by leading manufacturers as having definite influence on the balance sheet. Likewise these manufacturers are building better-looking plants than were formerly erected because they find there is a distinct prestige accruing to them from buildings that display good taste. Other things being equal, it is doubtful if any manufacturer would hesitate to choose a site facing an important main highway or an important railroad line in preference to a site on an unimportant traffic street or on a branch railroad. The difference in cost of the two properties, however, would have to be charged as advertising cost, and if it cannot be justified on this score the lower-cost site should be taken.

ULTIMATE COST—PRESENTATION OF REPORT

Summing up these various elements, it will be found that the ultimate choice should be of the site which has the lowest actual cost when completely developed with a plant. The purchase price of the land is but one factor, and often a minor one. The cost of drainage, foundations, grading, and other improvements on low-priced land may make it considerably more expensive in the long run than similar costs on land of much higher initial cost.

In presenting a location and site report to a client or a board of directors the conclusions and recommendations should be supported by a fairly detailed statement of the results found in studying each of the items in the above check list. It is of course very likely that the best location from a raw-material point of view will not coincide with the best location from the labor or distribution aspects. By presenting the preliminary conclusions reached upon each factor and showing how the conflicting elements were compromised in reaching the final conclusion, a great deal of argument and controversy can be eliminated.

This form of presentation is recommended both for location and site studies, the one being satisfactorily concluded before the other is undertaken. The engineer thus places before his employers the basic data upon which his recommendations are founded. If his work is thoroughly supported by evidence in the form of costs and experience records, the board of directors needs pass judgment only upon the soundness of his deductions. Debatable matters should be clearly indicated as such, so that the directors may decide for themselves upon any points which an outsider cannot analyze with the sureness of one more intimately acquainted with the history and probable destinies of the particular plant.

Air-Gas-Lift Practice in the Seminole Field

TWO general types of compressors are in use in this field, one being a small electric or gas-motor compressor, the other is a larger type usually direct driven from gas engines, though there are a few installations of the larger type driven by belts from gas engines.

The general method followed in equipping a well is described and illustrated by the author who also shows the arrangement of pipe connections for the output meter and describes the method of installation of the air-gas tubing at various stages of operation.

Wells have averaged about 4100 ft. in depth. The highest pressures in starting were about 1000 lb. per sq. in. and since the small compressors are built for this pressure no trouble was encountered in meeting these high pressures. High-pressure fittings are employed altogether. The highest working pressures were about 450 lb. which, of course, declined gradually with the age of the well. The lowest pressure employed was about 50 lb. on a small well making about 10 bbl. per day, equipped with a string of tapered tubing.

In some fields it has been of advantage to use "beans" or "chokes" in the flow line, thereby securing a high back pressure and for a short time conserving gas, but it was found at Seminole that the wells in many cases would cease to flow where any form of back pressure was applied. The lowering of a string of 2 or $2^1/_2$-in. tubing caused many a large well to cease flowing. The use of a bean is of advantage only where pressures are high, thus causing the well to act more in the nature of an artesian flow rather than as a gas lift. In this case the fluid level stands very high and the oil is "squeezed" through the bean; production is greatly reduced. As soon, however, as the pressure has declined and the fluid level reduced to a point where the well is acting mainly as a gas-lift, a bean causes the gas-oil ratio to increase to a high point. This effect is clearly shown by the results of the work of the Shell Co. at Dominguez, Cal. The same effect of conserving the gas can be secured by employing the proper size of tubing through which to flow the well, and the gas-oil ratio does not then increase to excessive points when the fluid level is lowered.

Considerable difficulty has been experienced in pumping small wells on the beam in the Seminole field. Two wells were accordingly equipped with tapered tubing to determine whether this was practicable. The results were quite satisfactory and subsequently several other wells were equipped in this manner with fully as good or better results than for the first wells.

As wells become smaller in production, the pressure drops, the lift increases, and the quantity of gas required to lift a barrel of oil is greatly increased over that necessary for a large well, and this quantity increases to an abnormal extent if the lifting be done through the same eductor as when flowing a large well. A consumption of 50,000 cu. ft. per bbl. could easily be reached in flowing a 10-bbl. well through the annular area between the 2 or $2^1/_2$-in. tubing and the $6^5/_8$-in. casing, whereas a proper size of taper-tubing would operate on 10,000 cu. ft. per bbl. or less, at 50 lb. pressure per sq. in., when flowing a well of this size.

When small wells are operated by gas lift the lifting costs become a matter of great importance. If the small electric-driven compressor that was employed for high pressures be employed for small low-pressure wells, the cost per 1000 cu. ft. of compressed air or gas will probably reach 7 or 8 cents, and at 10,000 cu. ft. per bbl. the cost would reach 70 to 80 cents with no allowance for interest or depreciation. On the other hand, gas can be compressed in a compressor direct driven from a gas engine at a cost of 3 to 4 cents per 1000 cu. ft. and the lifting cost then becomes 30 to 40 cents per bbl. which is considerably lower than would be the cost of a well on the beam, where frequent stoppages are caused by rod breakage, leaky valves, etc. (From paper by S. F. Shaw on Air-Gas-Lift Practice in the Seminole Field, before the Petroleum Division of the A.S.M.E., Fort Worth, Tex., Oct. 19–20, 1927.)

Shipbuilding in the United States

General Conditions of the Shipping Business Since the War—Shipping and Shipbuilding on the Great Lakes—Efficient Operation of Steam Plants on Lake Vessels—Competition Between the Motorship and New Types of Steamships—The Merchant Marine and National Defense

WHILE shipbuilding proper is supposed to be within the special domain of the naval engineer, mechanical engineers are legitimately interested in this industry, because after all a ship is a structure in the making of which mechanical-engineering methods and tools are employed. The naval engineer lays out the ship and superintends her construction, but shipbuilding creates a demand for steel, in the production of which mechanical-engineering methods are employed. It requires machine tools, boilers, engines, winches, and a thousand and one other appliances, all of which are designed or made by mechanical engineers. The prosperity or depression in our shipbuilding industry is therefore by no means a matter of indifference to the mechanical-engineering profession.

The situation of shipbuilding in America is at first glance not very encouraging. During the World War this industry had a mushroom growth to meet the unusual demands created by the sudden and urgent need for transportation across the water and powerfully emphasized by the destruction of shipping tonnage due to the activities of the German submarines. It was a time when questions of economy of operation, care in design, and reduction of costs were justly considered secondary in the face of one of the greatest national emergencies that history has known. Anything that would float and carry was worth while. The war was won and the victory was in no small measure due to the efforts of the American shipbuilding industry in the tragic years 1917–1918, but the legacy of this effort was a vast accumulation of ships admittedly poorly designed and built, and, because of this, highly uneconomical in operation.

It was not the United States alone that bent its most determined efforts to produce all the shipping tonnage possible. The English, Dutch, and Scandinavian yards were also working at fever heat. It so happened, however, that they had had far more previous experience than the newly created American shipyards, and hence were able, all things considered, to produce better vessels than those inherited from war years by Uncle Sam. When peace came war cargoes in men and materials were no more, and the shipping industry faced a world impoverished and upset by four years of fighting. As might have been expected, keen competition for commercial cargoes arose, and in this competition foreign shipowners with their greater experience and better equipment had a not unnatural advantage over ships flying the American flag

The Situation After the War

There were certain classes of war-time ship construction which proved to be absolutely hopeless under peace-time conditions. The great majority of wooden vessels belong definitely to this class. Careful investigation has shown, however, that when it comes to steel vessels, in particular Class A Shipping Board cargo ships, the situation is by no means entirely hopeless. As they stood, these ships were as a rule too slow and uneconomical to be operated without loss under the changed trade conditions. Post-war developments on the high seas showed, however, that everywhere in the world a powerful competitor to the old-style steam cargo vessel was appearing, namely, the motorship. And the Shipping Board began to look for ways to convert its war orphans into the more modern type of vessel by motorizing them. A revolving fund of $25,000,000 was placed at its disposal for this purpose by Congress, and a conversion program was initiated.

The end of the war did not help the shipping business of the world. While it would seem that the enormous destruction of merchant tonnage by German submarines should have been a factor in bringing about higher freight rates, the cessation of hostilities released such a vast number of bottoms previously engaged in the transportation of troops and military freight, mine laying, patrol duty, and similar war activities, and at the same time so decreased the demand for marine transports on the part of the allied and neutral governments that an unprecedented crash in marine freight rates resulted. For a while even good ships were a drug on the market, and in the years immediately subsequent the history of marine transportation once more demonstrated the truth of the old adage that iron men even in wooden ships are worth more than iron ships controlled by wooden men. The nations which had the best organizations for engaging in overseas carrying of goods and which knew most about the trade were the quickest to come back. A striking illustration of this is the rapid rehabilitation of the German merchant marine.

At the end of the war Germany was handicapped in many ways. There was undoubtedly a substantial residue of hostile feeling, especially among those who go down to the sea in ships or are connected with the shipping industry. The internal organization of German business suffered greatly from the collapse of the mark and the rearrangement incidental to the chopping off of several provinces which had previously played an important part in German industry. This refers particularly to the loss of the iron-ore deposits of Lorraine and the coal beds of Silesia. There was a decided lack of capital for new improvements, and out of the former merchant marine of 5,000,000 tons, barely 400,000 tons were left. Yet, in the face of all these unfavorable conditions and of the keenest competition for freight that the world had seen for decades, Germany succeeded in building up new tonnage which now amounts to 3,300,000 gross tons. Not only this, but the present German merchant fleet, according to a statement by Julius Klein, Director of the Bureau of Foreign and Domestic Commerce of the U. S. Department of Commerce (New York *Herald Tribune*, Sept. 25, 1927), consists almost entirely of new vessels in which the most recent developments have been incorporated. These include improved engines and fuel-saving devices tending toward greater speed and economy in operation, and as a result it may be said that while the gross tonnage of the present fleet is only 65 per cent of that of the German prewar total, the present fleet is nearly equal to the prewar in the volume of freight it can carry during a given period.

And that brings us to the question of what has happened to shipbuilding since the beginning of the war in the way of mechanical developments.

Up to a couple of years before the war all large vessels could be divided into two classes—sailing vessels and steamers. Small boats, including some fishing vessels, were, it is true, propelled by gasoline and oil engines, but these did not play any part in merchant sea transport. It was only on certain rivers, like the Volga in Russia, that cargo boats employed Diesel-engine drive, but even here the use of oil power was practically limited to vessels engaged in local transportation of fuel oil, and was not a factor in world commerce. It was only just before the war that the application of the Diesel engine to sea-going vessels was successfully accomplished, and, for example, the *Christian IX* startled the harbor folk in New Orleans and New York by its weird appearance and lack of traditional funnels and clouds of smoke.

The war delayed the application of Diesel engines to merchant ships, but helped improvements in the design of the engines themselves through their use in submarines. After the war the introduction of the Diesel engine went forward by leaps and bounds, and according to the latest information published by Burmeister & Wain, Ltd., of Copenhagen, Denmark, there were in July, 1927, as shown by Lloyd's Daily Index, 508 steel ships of over 2000 gross tons full powered with Diesel engines in actual service, representing a total gross tonnage of 3,105,039.

Spectacular Rise of the Diesel Motorship

From an engineering point of view the spectacular rise of the

Diesel motorship within the last six or seven years is not surprising. Steamship designers for many years have shown little spirit of progress. On the whole, the situation that lay before the Diesel was like that found by Sir Anthony Gloster of the Kipling ballad:

> They piddled and piffled with iron
> I laid my keel in steel.
> Steel and triple expansions—
> They captured the long-distance trade.

The result was that while on shore steam in central power stations made enormous progress in the way of increase in efficiency of operation and reduction of relative fuel consumption, the steam plant on the conventional cargo carrier remained largely unchanged from days long before the World War. The Diesel engine in the meantime made big strides forward, with the result that it could show better economy, practically equal reliability of operation, and what was more important, lower labor costs and increased cargo-carrying capacity. Tables 1 and 2, compiled from information supplied by a manufacturer of Diesel engines, give an idea of what has been accomplished.

TABLE 1 DATA ON CARGO VESSELS OF MEDIUM DIMENSIONS

	S.S. *St. Thomas*	M.S. *Paul Emile Javary*
Dimensions	310 ft. 8 in. × 40 ft. 6 in. × 29 ft. 9 in.	287 ft. × 45 ft. 9 in. × 21 ft.
Draft loaded	19 ft. 7 in.	18 ft.
Corresponding D.W.	3333 tons	3600 tons
Cargo space	147,700 cu. ft.	166,400 cu. ft.
Sea speed (actual service figures)	10.5 knots	10.25 knots
Length of engine room	56 ft. 5 in.	35 ft.
Total weight of machinery incl. of all accessories, shafting, etc.	340 tons	230 tons
Bunkers (20 days + 10 per cent)	420 tons	88 tons
Fresh water, stores, etc.	150 tons	60 tons
	570 tons	148 tons
D.W.	3333 tons	3600 tons
Net cargo capacity	2763 tons	3452 tons
It is thus seen that in this case the motorship's carrying capacity is about 25 per cent greater than that of the steamer.		
Fuel consumption per 24 hr. under normal conditions at sea	19 tons coal	4.0 tons oil fuel
Cruising radius under above conditions	6000 sea miles	14,000 sea miles
Engine-room staff	15	7

TABLE 2 DATA ON OCEAN-GOING LINERS

	S.S. *Stockholm* (oil-fired)	M.S. *Gripsholm*
Dimensions	547 ft. 1 in. × 62 ft. 1 in. × 34 ft. 6 in.	553 ft. × 74 ft. × 37 ft. 7 in.
Maximum draft loaded	26 ft. 3 in.	29 ft.
Gross tonnage	12,835 tons	17,993 tons
Sea speed	15½ knots	17¼ knots
Length of engine room and boiler room	138 ft.	112 ft. 6 in.
No. of cabin passengers		
1st class	245	129
2nd class	...	482
3rd class	852 1097	1006 1617
These figures show that the number of passengers in the motor liner is 47.4 per cent greater than in the steamer.		
Capacity of bunkers	2254 tons	2450 tons
Fuel consumption per journey out and home plus amount used in ports of call	2378 tons	1200 tons
Cruising radius under these conditions	6900 sea miles	13,800 sea miles
Number of double journeys carried out between January 1 and December 31, 1927	9½	10½[1]

[1] To this must be added a summer cruise in the Baltic.

Comparatively low prices for oil during the last five years due to vastly increased production in this country and the opening of new fields in various parts of the world were also a contributing factor.

The success of the Diesel engine on shipboard had a reaction in the United States different from that in England. The former practically capitulated to it unreservedly; the latter is beginning to show signs of fight. Reference has been made to the Dieselization of Class A vessels by the U. S. Shipping Board. The first program of conversion made possible by the grant of a revolving fund of $25,000,000 by Congress seems to have been attended by commercial success, as a result of which the second conversion program is now under way. Bids on direct-drive Diesel engines for this second program were opened in New York on August 15, 1927, by Capt. R. D. Gatewood, the Manager of the Maintenance and Repair Division of the Merchant Fleet Corporation. Bids were invited on main engines of the single-acting or double-acting two-cycle or four-cycle types of 3500 to 4000 b.hp. at 95 to 115 r.p.m. The Board, however, permitted the engine manufacturers to submit engines of higher speeds where the design allows such speed at continuous operation. Air injection of fuel is stipulated by the Shipping Board for all engines, the injection air compressor to be driven off the forward end of the engine crankshaft. In the case of two-cycle engines alternative proposals were asked for direct-driven scavenging pumps and independent scavenging blowers supplied in duplicate. In addition to this the U. S. Shipping Board has worked out certain changes in the design of hulls of the ships included in the conversion program, and it is expected that these changes can be carried out at a comparatively low cost and will result in material increase in speed of the converted vessels. In addition to the direct-driven ships, two will be fitted with Diesel-electric drives. No specifications for these have as yet been issued.

The American merchant marine (not considering the Great Lakes and coastwise shipping) may be said to have started from scratch, nothing of importance in that form having existed in the generation that saw the beginning and end of the World War. There was absent that familiarity with and love for steam as a prime mover ingrained in the British shipbuilder and operator. It was natural, therefore, that in England there was no inclination to accept without opposition the effort of Diesel manufacturers to drive out steam, a subject of rather hot discussion at several meetings of British technical and commercial organizations.

STEAM POWER VS. DIESEL POWER

One of the best sets of arguments on the subject from both sides was presented at the Spring Meeting of the Institution of Naval Architects (British) in April, 1925. At a meeting of the Royal Society of Arts on February 11 of the same year a prominent British engineer, Sir Fortescue Flannery, read the following sentence of death on the steam engine: "The use of Diesel machinery for navigation will become so common that only for special purposes will the steam engine be able to hold its place." This is a view, however, which has by no means been as yet universally accepted among British shipbuilders. According to Sir John Biles, the relative merits of steam and Diesel engines for ship propulsion depend on three factors: *a*, the relative first cost; *b*, the relative cost of Diesel and boiler fuel; and *c*, the relative working cost, including crew and maintenance.

The construction of Diesel engines of large powers has not been sufficiently stabilized or sufficiently extensive to make it possible to standardize the manufacture so as to insure the lowest possible first cost. The double-acting engine, which promises to be the least costly to produce, is more or less experimental, and under such circumstances is not likely to have reached the lowest possible cost of production. On the other hand, steam boilers and turbines have probably reached very nearly the highest economy of production costs, as they have been produced for many years and in large numbers.

The relative cost of boiler and Diesel oil fuel suitable for ship propulsion seems to be a variable quantity. The difference in cost varies from nothing to 20 per cent in favor of the boiler-fuel oil. There are some oils of about the same thermal efficiency which can be used in a boiler which cannot or have not been used in a Diesel engine, and even if they are used it has been estimated that the cost of the Diesel oil might be nearly 20 per cent higher without being superseded by the oil suitable for a boiler. It seems probable that for some time to come the oil fuel for the steam engine will be cheaper than for the Diesel.

The cost of the crew for the Diesel-engined ship will quite probably be less than for the turbine-driven ship in high-powered vessels, but for powers below 10,000 hp. this does not seem to hold. As to the relative cost of maintenance and repair, it is too early to dogmatize. These costs in the cases of the turbine and boilers are known and are not high. The number of moving parts of a Diesel engine is very large and the liability to wear and damage is not small, but until the latest types have been at sea for some time we must wait for full knowledge on the subject.

As far as can be judged from the data available, it seems to be probable that the turbine will give results in commercial efficiency which will make it a strong competitor of the Diesel.

It is therefore not the Diesel alone which will make existing steamers obsolete, but also developments in the steam engine itself which are very likely to produce the same results. The gain of the Diesel over the steam engine is in the smaller consumption of oil per unit of power, but the cost and weight of the Diesel are much greater than those of turbine installations using high-pressure steam in the way suggested by Sir Charles Parsons.

A further claim is made for the Diesel engine, namely, that in the case of passenger ships, more space is available for passengers than in steamships. Sir John Biles tries to answer all these questions by comparing designs for ships of different sizes and lengths of voyage; the types included being Diesel engines, steam turbines of existing types of machinery with cylindrical tubulous boilers, and steam turbines working at 500 lb. pressure and 700 deg. temperature from water-tube boilers as proposed by Sir Charles Parsons. This latter is referred to as the H.P.T. type and will be described further.

TABLE 3 ANNUAL COSTS FOR VOYAGES TOTALING 120,000 MILES

	Diesel	Steam	H.P.T.	Diesel	H.P.T.	H.P.T.
Sea speed, knots	20	20	20	17	17	18
Shaft horsepower	27,000	28,000	27,000	13,500	13,500	16,900
Cost of machinery	£460,000	£380,000	£333,000	£240,000	£175,000	£210,000
Interest, depreciation, insurance, and maintenance per year	£ 85,100	£ 70,390	£ 61,605	£ 44,400	£ 32,380	£ 38,850
Distance covered per year, miles	120,000	120,000	120,000	80,000	80,000	80,000
Fuel burnt per year, tons	36,160	75,000	50,625	14,180	19,853	23,472
Cost of fuel per year	£144,640	£243,750	£164,531	£ 56,720	£ 64,522	£ 72,287
Lubricating oil per year, tons	337.35	7.03	6.78	132.3	2.66	3.14
Lubricating oil, cost per year	£ 11,554	£ 241	£ 232	£ 4,531	£ 71	£ 108
Feedwater for boilers per year, tons	2,025	28,000	13,500	794	5,294	6,259
Cost of feedwater for boilers per year	£ 160	£ 2,127	£ 1,068	£ 63	£ 419	£ 495
Engine-room wages per year	£ 10,000	£ 12,000	£ 11,000	£ 6,600	£ 8,000	£ 9,000
Total running expenses	£166,354	£258,208	£176,831	£ 67,914	£ 73,012	£ 81,890
Charges	85,100	70,390	61,605	44,400	32,380	38,850
Total	£251,454	£328,598	£238,436	£112,314	£105,392	£120,740

The weights of Diesel engines and steam-turbine plants in existing sizes are very much the same, while the weight of the H.P.T. type is from 40 to 50 per cent less than that of the Diesels. When we come to the question of fuel consumption per shaft horsepower on shipboard, the question of auxiliaries is apt to bring in a disturbing element. The figures presented in this case are 0.5 lb. per hp. for Diesels, 1.05 for ordinary steam turbines, and 0.7 for high-pressure turbines, all including auxiliaries.

Table 3 shows annual costs for voyages totaling 120,000 miles for two vessels, one of 20 knots speed and the other of 17 knots. From this table it would appear that in the case of 20-knot vessel the Diesel type of engine cost £13,000 (say, $65,000) per year more to run than steam, while at 17 knots the cost here of the Diesel engine is £7000, say $35,000, more than for steam.

High-Pressure, High-Temperature Steam Equipment a Possible Formidable Competitor of the Diesel Engine

It would appear, therefore, that if the high-pressure-type equipment can be made sufficiently reliable for marine service and can be operated in the way indicated here, it would make a formidable competitor of the Diesel engine. The possibilities of such equipment have been presented in a paper by Sir Charles A. Parsons before the North East Coast Institution of Engineers and Shipbuilders in the latter part of 1926.

Sir Charles, whose name is associated with the whole history of development of the steam turbine, gives a table showing how the size of turbines used on shipboard increased and their efficiency improved. The introduction of gearing between the turbine and propeller has brought a further improvement. For higher pressures from which a still further advantage may be derived, it is said to be necessary to adopt water-tube boilers, and Table 4 gives what is supposed to be the overall result that may be expected with an installation of high-pressure turbines under four different methods of driving auxiliaries.

TABLE 4 EVALUATION OF OIL-FUEL CONSUMPTION OF A 5000-S.HP. INSTALLATION

Conditions:

Initial pressure	500 lb. per sq. in. (abs.)
Initial temperature	750 deg. fahr.
Condenser vacuum	29 in. mercury (Bar. 30 in.)
B.t.u. per lb. of oil	18,500
Boiler efficiency	84 per cent

	1		2	3	4
	Steam-driven auxiliaries		Steam-electric auxiliaries	Diesel-electric auxiliaries	Auxiliaries driven from main engines
	A	B			
Turbine steam, lb. per hr	36,000	36,000	36,000	36,000	36,000
Total steam for auxiliaries, lb. per hr	8,960	8,960	7,650	2,450	2,450
Available for feed heating, lb. per hr	7,210	7,210	5,900	850	850
Utilized for feed heating, lb. per hr	5,800	5,800	5,700	4,950	4,950
Utilized in low-pressure turbine, lb. per hr	...	1,410	...	...	...
Increase of shaft hp.	...	98	...	...	...
Tapped off from low-pressure turbine, lb. per hr	...	...	...	4,100	4,100
Decrease of shaft hp	...	...	...	285	285
Horsepower absorbed by auxiliary machinery in (4)	...	...	...	...	132
Shaft horsepower for propeller shaft	5,000	5,098	5,000	4,715	4,583
Total steam, lb. per hr	44,960	44,960	43,650	38,450	38,450
Oil for steam production, lb. per hr	3,405	3,405	3,310	2,910	2,910
Oil for Diesel generator, lb. per hr	...	...	...	82.5	...
Total oil, lb. per hr	3,405	3,405	3,310	2992.5	2,910
Lb. oil per shaft hp-hr. at 215 deg. fahr. feed temperature	0.681	0.668	0.662	0.635	0.635
Lb. oil per shaft hp-hr. at 310 deg. fahr. feed temperature	0.667	0.655	0.648	0.62	0.62

The installation of main machinery to which this calculation applies is that of a single-screw cargo vessel of 5000 s.hp., with an admission steam pressure of 500 lb. per sq. in., initial temperature of 750 deg. fahr., condenser vacuum of 29 in. mercury, and an assumed boiler efficiency of 84 per cent. Additional feed heating to a temperature of 310 deg. fahr. is effected by steam tapped off from the main turbines at a suitable high-pressure stage.

Summarized, the resulting values for oil fuel consumed per shaft horsepower-hour are as follows: Proposal 1, with steam driven auxiliaries, 0.667 lb.; Proposal 2, with motor-driven auxiliaries and turbo-generators, 0.648 lb.; Proposal 3, with motor-driven auxiliaries and Diesel generators, 0.62 lb.; Proposal 4, with auxiliary machinery mechanically driven from the main engine, 0.62 lb.

There is already on the high seas a Clyde-built steamer, *King George V*, equipped with high-pressure machinery and having a power of 3500 s.hp. on two shafts, a boiler pressure of 550 lb. per sq. in., and steam superheated to 750 deg. fahr. The economical effect of adopting high pressures would have been considerably greater in an installation of larger power.

The propelling machinery consists of a set of three turbines, geared by single reduction to each propeller shaft, such as has been frequently adopted in previous geared-turbine installations, but in this vessel one additional high-pressure turbine is fitted to utilize the expansion of the steam from 550 lb. to about 200 lb. This high-pressure turbine is connected in tandem with the first turbine on the port shaft, and in order to balance the power of the shafts, the main turbines are so designed that a larger proportion of the steam from the high-pressure turbine passes to the turbines on the starboard shaft. A high-pressure astern turbine is provided in each of the first intermediate ahead turbines, and a low-pressure astern turbine in the casing of the low-pressure ahead turbine in the usual manner. The total shaft horsepower developed on the two shafts is 3500 at a speed of 570 r.p.m. for the propellers. The high-pressure turbine and the two intermediate-pressure turbines of each shaft run at 6000 r.p.m. and the low-pressure turbine at 3000 r.p.m. Of the total power the high-pressure turbine contributes about 600 shaft hp. The boilers are coal-burning, two in number, of the Yarrow water-tube type, designed for a working pressure of 550 lb. per sq. in. with superheater elements to raise the temperature of the steam to a maximum temperature of 750 deg. fahr., surface air heaters in the uptakes to heat the air on its way to the grates, and a closed-stokehold system of forced draft.

The trial results of the *King George V* at various powers are quite encouraging. The coal consumption was 1.085 lb. per s.hp-hr. at an output of 3489 s.hp., and 1.17 lb. at 2083 s.hp.

The *Times Trade and Engineering Supplement* (London) of Sept. 12, 1925, announced the construction of another high-pressure steam vessel. This is now being built at the works of William Denny & Bros., Dumbarton, and it is stated that the twin-screw turbines will be of 4000 hp. and will operate through mechanical reduction gearing. They will be supplied with steam by two water-tube boilers working at a pressure of from 500 to 550 lb.

per sq. in. and at a temperature of from 700 to 750 deg. fahr. The steam pressure will thus be double that of any existing marine installation. The water-tube boilers will be fitted with air preheaters, the steam for the auxiliary machinery will be used at a reduced pressure, the auxiliary exhaust steam will be utilized for heating the feedwater to about 200 deg. fahr., and the temperature of the feedwater will be increased to about 300 deg. fahr. by steam tapped off from the turbines.

The construction of high-pressure marine steam plants is not limited to England. The *Malolo*, built by Wm. Cramp & Sons' yards at Philadelphia for the American-Hawaiian Steamship Co., also belongs to the same class. This will have twelve water-tube boilers of the Babcock & Wilcox marine type, built for a working pressure of 280 lb. gage and at least 100 deg. superheat, which is considerably below the pressure and superheat for the *King George V* but above anything previously employed in American commercial practice. The boilers are equipped for burning oil under forced draft.

Shipping and Shipbuilding on the Great Lakes

Those who take a gloomy view as to the ability of this country to handle marine transportation may find at least a partial assurance in what is happening on our inland seas, the Great Lakes. During the limited season of lake navigation, the bulk freight movement in 1926 attained the high record of 121,289,502 net tons of iron ore, coal, stone, and grain. This is a truly enormous amount. It was carried by lake, because water transportation afforded the cheapest means of moving such freight. At the same time it should be noted that from a commercial point of view there was here merely competition with other means of transportation, such as railroads, which for the most part were not equipped to handle such freight at all. There was no competition with foreign commerce in this kind of traffic.

According to the annual report of the Lake Carriers' Association for 1926, the policy of vessel owners is that lake seamen shall continue in the enjoyment of the best saving wage paid to seamen in any waters of the world, and the equitable methods employed in the operation of the welfare plan have been a compelling factor in the long-continued friendly relations between the members of the Lake Carriers' Association and the workers that man the ships.

Eighteen seasons of navigation have now passed without a single revision having been made in this original arrangement of relations between employer and employee. And during this long period nothing resembling serious differences, let alone conflict, has arisen. Seamen—of acutely discerning mind—are cognizant of the efforts constantly made to imrove conditions aboard ship. The wholesome quarters provided for them in 15 different ports while they are ashore waiting employment has had an appealing effect. Their approval of the several features of the welfare plan is attested by the spirit of coöperation they lend to the movement to prevent personal injuries and to the clearer visualization of the fact that the savings plan and the educational program are institutions created solely for their well-being without any ulterior motive. The purpose of the welfare plan has become so well defined that registration is sought not only for the advantages that accrue while in the lake service but from the expediency registration serves when seeking employment elsewhere, procuring naturalization papers, licenses, hospital services, war bonuses, etc. There is little cause for wonder, therefore, that in busy seasons of navigation the total registrations in the welfare plan exceed 20,000, and that in the exceptionally brisk season of 1926 the membership should have risen to the second largest of any year.

Moreover, lake seamen keep in close touch with all seafaring conditions. They are not unmindful of the fact that during the past three years cargo capacity has been curtailed and freight rates have been reduced without a reduction in their own wages having been made.

In contradistinction to the downward trend in seamen's wage scales generally, the recommended minimum rates of wages of the Lake Carriers' Association have continued without change for three consecutive years. When generous advances were made at the beginning of 1923 for all those in the lake service below the grade of licensed officers, freight rates based to the head of Lake Superior were 80 cents a gross ton on ore and 45 cents a net ton on coal. At that period, too, recommended loading drafts averaged slightly in excess of 19 ft. 6 in. to ports on both Lake Superior and Lake Michigan. By reason of low water there has since been an unmistakable lessening in the amount of cargo a vessel could load, hence a reduction in earning capacity per trip each way. Moreover, ore and coal have been carried each year since 1924 at the reduced rates of 70 cents and 40 cents per ton, respectively.

That successful operation of lake vessels reflects on the condition of that branch of shipbuilding is illustrated by the 28th Annual Report of the American Shipbuilding Co. for the fiscal year ended June 30, 1927. In this year there was a net profit of $1,747,373.51. In his report the president of the company, A. G. Smith, points out that the favorable condition shown in the earnings of the year (more detailed figures will be found in *Marine Review*, Oct., 1927, p. 23) was largely due to the volume of business in contracts for new tonnage, comprising five bulk-freight steamers, one large bulk unloader 600 ft. in length overall, and one tug. Contracts have been also closed for the construction of two oil tankers for operation on the Great Lakes to be delivered during the spring and summer of 1928. Two oil-carrying barges were also built for the Standard Oil Co. of N. J. for use in New York harbor and vicinity.

Efficient Operation of Steam Plants on Lake Vessels

In preparing this article an effort was made to procure information as to horsepower and fuel consumption on lake ships so as to obtain an idea whether or not power-plant engineering on lake vessels has kept pace with the development on land. Just what the fuel consumption per shaft horsepower is will vary with the coefficient of mechanical efficiency assumed, and it will be noted that this assumption varies from 86 per cent to 58 per cent (Table 5) on the various lines. On the whole, however, the fuel

TABLE 5 DATA ON FUEL CONSUMPTION ON LAKE VESSELS FURNACED BY OPERATORS

G. A. Tomlinson, Cleveland, Ohio

Company	Steamer	Indicated hp.[1]	Lb. coal per hr. for all purposes on ship
Panda S.S. Co.	*W. H. Warner*	2241	3578
Globe S.S. Co	*James Davidson*	2157	3159
Globe S.S. Co	*Frank C. Ball*	1949	3162
Superior S.S. Co	*George G. Barnum*	1836	3005
Globe S.S. Co	*Cuyler Adams*	1608	2646
Inter-Ocean S.S. Co	*Sierra*	1422	2336
National S.S. Co	*F. W. Hart*	1412	2400

[1] As all of engines of the steamers listed have attached air pumps, the mechanical efficiency is about 86 to 87 per cent.

M. A. Hanna Co., Cleveland, Ohio

This company has 15 steamers, all equipped with jet-condensing, triple-expansion engines carrying 180 lb. of steam; cylinder dimensions on all of the vessels are 23½ in., 38 in., and 63 in. bore by 42 in. stroke. All at their regular running gaits are working about 1650 to 1700 hp. All are equipped with two 3-furnace Scotch boilers and are averaging 1½ lb. of coal per hp. One vessel, the *W. A. Amberg*, has furnaces of 46 in. inside diameter, and swings a 14-ft. 6-in. propeller of 14 ft. 6 in. pitch; another, the *E. N. Saunders, Jr.*, swings a 14-ft. 3-in.-diameter propeller of 15 ft. pitch. All vessels are averaging close to 11.5 miles per hour outside. Engines are capable of working up to 2000 hp.

The Wilson Transit Co., Cleveland, Ohio

No actual data on effective horsepower are available, but on lake-type cargo vessels it is the common practice to assume 0.58 as the relation between indicated horsepower and effective horsepower.

On two ships the following results have been secured which are believed to be fairly representative:

Total I.hp.	Coal consumption, lb. per hr.
2268.0	4543.50
2369.2	4220.45
Average 2318.6	4381.97

Applying the coefficient of 0.58 to the average i.hp. above, the following results are obtained:

Average effective horsepower	1344.79
Average coal consumption lb. per hr	4381.97

consumption on lake steamers compares not at all unfavorably with that in good power plants, and bears eloquent witness to the high grade of engineering talent employed in the design and construction of lake ships.

We see, therefore, a rather peculiar situation. The American seagoing merchant marine in tonnage is second only to the British. At the same time neither financially nor generally has it shown any specially encouraging results. Outside of the vessels on the Great Lakes this merchant marine consists either of vessels taken over from other countries or built under the pressure of war; and since the war, shipbuilding for the high seas has been little better than moribund. One of the oldest yards, the Cramp Shipbuilding

Co., of Philadelphia, has gone entirely out of existence. The majority of others are carrying on but are not happy.

In part, of course, world shipping conditions are responsible for this state of affairs, but only in part, because under the same conditions and under handicaps from which the American merchant marine was free, the Germans have greatly expanded their merchant marine. And if they were able to do it why could not the Americans have done it?

Three reasons are often cited, none of which it is desired to discuss here in detail. One is Government interference, or methods of Government control of merchant shipping. Another is the so-called LaFollette-Furuseth law under which merchant vessels under the American flag have to pay higher wages than foreign vessels and are restricted in the choice of employable personnel.

In connection with passenger transportation in particular, American vessels are said to be suffering from a disadvantage as compared with foreign vessels in that they are subject to the Volstead law while on the high seas, from the operation of which foreign vessels are exempt. However, it is obviously impossible to determine exactly to what extent this has been a material factor in the situation.

Two important suggestions have been lately made to help this situation. One was that American importers should insist on having goods shipped to them in American bottoms. This, however, is obviously only a partial solution and not generally applicable, particularly where the foreign material is sent to an agent in this country rather than directly to the purchaser of the goods, as is the case, for example, with potash, pig iron, cast-iron pipe, and many other commodities.

The second suggestion is that the law prohibiting American railroads from owning vessels should be repealed. In this connection it is generally stated that, for example, German shipping gains materially from its very close coöperation with the state-owned railroads. This is, however, again only a partial solution at best, and one from which relief cannot be expected for a good many years. The entire railroad situation is today in a state of uncertainty, because of the apparent great difficulty of putting into effect the railroad merger provisions of the Esch-Cummings Transportation Act. As is generally known, this act permissibly provided for a merger of railroad lines and by way of suggestion proposed a group of merger plans. Since its passage, however, the formation of the so-called Van Sweringen and Loree groups has thrown the Ripley-I.C.C. plan of mergers into the discard. Furthermore, the rejection by the I.C.C. of the first Van Sweringen plan based on the Nickel Plate System and of the Loree Southwestern merger, as well as of the leasing plan of the New York Central Lines, and of the Buffalo, Rochester, and Pittsburgh Railroad lease by the Delaware & Hudson in the second Loree plan, together with the strong opposition already developed to the second Van Sweringen plan based on the Chesapeake & Ohio, and to the Northern Pacific merger plan, would indicate that the whole problem of railroad mergers and related parts of the present Transportation Act will be thrown back into Congress. Under these conditions it is practically impossible to expect that Congress will do anything in the way of increasing the powers of the railroads by way of permitting them to own seagoing ships before it knows definitely what size and character the railroad groups will have and before it has worked out ways to permit railroad mergers.

The Merchant Marine and National Defense

The national-defense value of the merchant marine must not be overlooked. Admiral E. W. Eberle, Chief of Naval Operations, U. S. N., in a recent article in the *Proceedings of the U. S. Naval Institute* (October, 1927) cites the following, which is quoted verbatim.

> The national wealth of the United States is estimated to be well over $400,000,000,000. Our annual export trade is close to $5,000,000,000. It is approximatley the same as the export trade of Great Britain, and exceeds the export trade of any other country. Not only does our annual export trade equal or exceed that of any other nation but, in addition to this export trade, the value of our coastwise trade, excluding the traffic on the Great Lakes, is greater than the value of the total foreign trade of any other nation. Otherwise stated, the value of our foreign commerce plus the value of our coastwise traffic is more than twice the value of the foreign commerce of any other country. Our coastwise trade extends from Maine to Alaska, covering a distance only slightly less than that from England to Australia.
>
> The nation that furnishes transportation (ships) has in its hands a powerful factor in peace-time overseas trade. In war time such a nation has in operation a merchant fleet which continues to transport goods of all descriptions to and from home in order to supply the needs of the population; transports the raw and manufactured materials essential to the conduct of war; transports supplies of all description for the fleet; transports men and munitions overseas. The merchant fleet also augments the actual fighting strength of the fleet by the addition of fast liners mounting 6-in. guns. Such ships make very efficient fleet units capable of engaging successfully any type of warship except the capital ship and the cruiser mounting 8-in. guns.
>
> Thus a vast merchant fleet constitutes in itself a powerful element not only of fleet strength, but of the strength of the nation both in peace and war. In computing the strength of navies or nations the capabilities of the merchant fleet constitute a factor which must be carefully evaluated.
>
> Since the number of ships in our merchant marine permits only a portion of our enormous sea-borne commerce to be carried in American bottoms, a greater national force is required to protect it than would be necessary were it all carried in American bottoms.

How, then, may the general situation of American shipping and shipbuilding be viewed? It is unquestionable that political and legal considerations and that indispensable background of knowledge of international trade and transportation which the European nations have collected for centuries and the Americans are rapidly building up, profoundly affect the development of a national merchant marine. In the long run, however, it is the cost of transportation that will decide the battle for the carrying of world goods on the high seas. The Americans had practically a monopoly of carrying certain classes of goods in the days of the fast clipper ships. The English captured a similar favorable position when they first came out with nine- to eleven-knot freighters. Of late the same feverish competition between industries and methods that marks business generally has spread to shipping. Today it is a fight between the Diesel engine and steam. In the first round the Diesel engine won, as indicated by the extensive construction of motorships and in this country by the conversion to Diesels of Class A Shipping Board vessels. That steam cannot be considered to have been knocked out for good hardly needs argument. As a matter of fact, it is strongly coming back, as indicated by British efforts to introduce high-pressure boilers for marine work. The surprisingly economical operation of the big boats on the Great Lakes from the point of view of fuel consumption is also an encouraging sign for the friends of steam. It is for the future to show which will win. And should steam win the United States may have cause for congratulation in that it has made only a comparatively modest investment in Diesel-type motorships. That steam has, in the opinion of some engineers, an excellent chance to win is indicated by the rapid and thorough improvements in land generation of power by steam which has now reached such a high degree of efficiency that it is only under exceptionally favorable circumstances that water power can compete with steam in the generation of energy. The *King George V* is already a great step forward as compared with previous practice in the application of steam for marine purposes, and an American power-plant engineer would see many ways in which the power plant of the *King George V* could be improved by the adoption of methods and designs which have fully established their value in land practice.

Contrary to the generally accepted opinion, there does not seem to be any superfluity of bottoms, and economically operated vessels seem to be able to find paying cargoes. The world's commerce is increasing, more freight is being carried all the time, and it should not be forgotten that the United States is second on the list of owners of merchant marine. The shipbuilding industry in this country is in the dumps today, except for the demands of coastal and Great Lakes shipping, because in the first place it has been left with a large number of bottoms of war-time construction, vessels which are too good to be deliberately destroyed and not quite good enough as they are to be operated at a profit. In the light of the fact that from a technical point of view shipping is passing through a period of transition and that no one knows today whether the Diesel engine or some modified steam method will prevail, there is no special inducement for capital in this country to go into new shipbuilding. It is, however, apparently a temporary lull only, and very much greater activity in American shipyards may be expected, possibly at an earlier date than is generally anticipated.

Industrial Mobilization for National Defense

By CHARLES M. SCHWAB,[1] NEW YORK, N. Y.

IN TIMES past, we Americans have been all too ready to assume that preparation for a possible national emergency consisted almost entirely of planning for the mobilization of man power, forgetting the fundamental fact that men without rifles or field guns and the necessary ammunition are not soldiers. If there was one great lesson that stood out above all others as a result of our experience during the World War, it was the demonstrated fact that, relying solely upon our own resources, we could call to the colors, organize into units, and train our citizenry at a rate which far surpassed any possible rate at which we could equip them with the necessary ordnance.

I am inclined to think that this condition will always obtain in America, namely, that the supply of ordnance will be the critical factor in any program for national defense, and as you young gentlemen are some day destined to be entrusted with making proper decisions which have a vitally important bearing upon our continued existence as a nation, I want to set you thinking upon a phase of national defense which, in my opinion, the military mind has too often been apt to dismiss as being of relatively little importance.

You all know that we are living in an age when machine power is to a greater and greater extent supplanting man power. We have developed machinery not only for manufacturing purposes, but for lightening the burdens of housekeeping and for purposes of recreation and enjoyment. This is a machine age and, unfortunately, the same underlying factors are working to place warfare to a greater and greater extent on a machine basis. In the Spanish-American War we had perhaps a half-dozen machine guns as the total equipment of all our Army in Cuba. At the outbreak of the World War we had increased the use of this weapon to about a half-dozen per regiment. By the time of the armistice we had increased the use of machine guns by practically 2000 per cent. Other mechanical weapons, such as tanks and railroad artillery, were developed and used in increasing quantity. The use of airplanes for military purposes was conceived and developed to a tremendous extent, all within a period of about four years.

Now it is altogether probable that the use of mechanical devices in warfare will continue to increase, and the proper solution of the ordnance problem will be of even greater importance than it was during the World War. If that is so, the question that you generals of the future are going to be most concerned with is, "Where and when can we obtain ordnance?" If that question cannot be answered satisfactorily, and arms and ammunition of suitable quality and adequate quantity cannot be supplied sufficiently early in the mobilization program, all other well-laid plans will prove futile.

Civilian Manufacture of Ordnance Fast Becoming a Lost Art

It may be contended that the Army officer's job is training soldiers and mobilizing man power, and that industry should stand ready to provide the arms and ammunition needed to convert citizens into soldiers, but that is not in accord with conditions today. The nation holds you military men responsible for taking all necessary measures to provide for the national defense in emergency. Industry is busily engaged in its peace-time pursuits endeavoring to meet competition in world markets. It is against the traditional policy of America to encourage a civilian munitions industry. Certainly, today it can be said that the manufacture of ordnance is fast becoming a lost art in so far as civilian industry is concerned.

Before the World War, America possessed several large civilian manufacturing plants devoted in a greater or lesser degree to the manufacture of field artillery, ammunition, and other articles of ordnance, including among others my own plant at Bethlehem, but today the Bethlehem Steel Corporation has definitely abandoned any thought of ever again engaging in the manufacture of ordnance except in times of the greatest national emergency. All the civilians who had learned to design and manufacture cannon, armor plate, and other items of ordnance are now devoting their time to entirely different activities. In general, this same condition obtains with respect to other commercial plants engaged in the manufacture of ordnance prior to the World War. This situation places an increasing great responsibility on the Army, one that you military leaders of the future must take into consideration. You cannot begin too young to think of war as a vast industrial undertaking.

You are probably wondering why I have not placed aviation material in the same category as ordnance. It is for this reason: interest in aviation and activity in the manufacture of airplanes and accessories is increasing by leaps and bounds. The problem of providing aircraft for an expanded army is working toward ultimate solution. Exactly the opposite is the case when we consider ordnance. Fewer and fewer of our factories are able to produce rifles and ammunition.

Too Few Army Officers at Present Assigned to Activities Indispensable in the Mobilization of Industry

We have, perhaps, 17 million physically fit men of military age, we have such Government-supported institutions as the Regular Army, the National Guard, the Organized Reserves, the Civilian Military Training Camps, the National Rifle Matches—organized to train man power in the use of arms, presumably on the assumption that the necessary arms and ammunition will be ready in the quantities and at the times needed during mobilization. But the truth of the matter is that we are doing relatively little to educate industry in the manufacture of arms. To the business man sizing up the whole problem of national defense, it sometimes appears as if too many regular-army officers are assigned to duties in connection with the mobilization and training of man power for use in the event of emergency, and entirely too few officers are assigned to activities leading toward the solution of a far greater problem, the mobilization of industry to provide the necessary arms and ammunition for an expanded army.

Now you all know that it is easier to learn to drive an automobile than it is to learn to make one. By the same token it is easier to teach a man how to shoot a rifle than it is to teach a mechanic how to make it. Incidentally, the rifle has to be manufactured before it can be used. So I would like to raise the question in your own minds as to whether we are not unduly emphasizing the man-power problem at the expense of the munition-power problem.

We accomplish such wonderful things in America in the way of mass production that we sometimes lose sight of the great amount of preliminary work that must be done, and the great length of time which must necessarily elapse, before mass production can be attained. We hear of some great automobile factory turning out a complete automobile ready to run under its own power, at the rate of one every minute or so during the day. We lose sight of the fact that, perhaps, two solid years of preparatory effort has been required to design jigs and fixtures, to determine the most effective layout of machinery, to design special-purpose machinery, to recruit and train the employees into a smooth-working unit. All of these things have to be done before even a single car comes off the assembly line. Even then we are apt to find that some of our calculations have been in error; that some of the parts do not go together as smoothly as we could wish. So there is a period of readjustment, re-routing, and general tuning up before we attain the huge production which amazes the casual visitor.

In considering national defense, it is apparent that the peace-time life of a nation keeps alive and increases the knowledge necessary to the organization and employment of an expanded Army with two vital exceptions: (*a*) Training in the use of arms, and (*b*) education in the manufacture of arms.

Army Should Be Munitions-Power Minded as Well as Man-Power Minded

Under great handicaps our Army has, in the past, kept alive the

[1] Chairman, Bethlehem Steel Corporation; President, A.S.M.E.

From an address before the Corps of Cadets, U. S. Military Academy, West Point, N. Y., May 12, 1927, on the occasion of the First National Meeting of the National Defense Division of the A.S.M.E.

necessary knowledge in regard to the use of arms. If present conditions obtain in the future our Army will also be faced with the problem of keeping alive the necessary knowledge involved in the manufacture of arms, and you young gentlemen of the Military Academy, while your minds are open to new impressions and new ideas, must undertake the job of making the Army munitions-power minded as well as man-power minded.

The engineers, chemists, and manufacturers of America stand ready to work with the Army in preparing for national defense. Industry understands perfectly well how to feed, clothe, transport, shelter and provide communications for the largest army we would possibly organize, because industry now has and is expanding its knowledge of these activities common to both our peace-time and war-time pursuits. The medical, surgical, and dental professions can provide all necessary care and attention because they are being automatically schooled in peace time for the war-time duties. But, industry does not and cannot as a result of its peace-time activities keep alive the knowledge necessary to the production of ordnance in the quantities demanded by an expanding Army, in order to give it at least an even break with the enemy.

There you have the crux of the whole question of national defense, namely, the ordnance problem. You may ask what can be done toward its solution. The one and only thing we can do in times of peace is to have more knowledge of ordnance manufacture promptly available at the outbreak of war, and the only way we see to bring about this condition is to have more trained ordnance officers available in emergency. I have been told that there are 60 Regular Army officers in New York City alone, assigned to teach National Guard and Organized Reserve units the elements of military science and tactics—in other words, the use of arms. The hundreds of plants in the metropolitan area which would be called upon to manufacture ordnance in emergency, and which now stand ready to work with the Army in making plans to that end, have but one Regular Army officer to whom they can turn for necessary information.

Under present-day conditions we must have a far greater proportion of our officers take their training at the various arsenals, where the art of ordnance manufacture is kept alive on a laboratory basis so that they, in turn, can be detailed to duty at various commercial manufacturing plants for the purpose of assisting manufacturers in assembling the vast amount of preliminary data in the shape of drawings for tools and jigs and fixtures; design of working gages; computation of schedules for raw materials, semi-finished components, and additional equipment; the layout of highly specialized machinery, and estimate of additional power requirements. It is only in this way that we can hope to shorten the gap between the declaration of war and the date when our unlimited man power will be adequately armed and supplied with the increasingly great quantities of ammunition which modern warfare demands.

Do not let the lesson of the World War be obscured by the fact that our own deficiencies in ordnance production were offset by the generous offers of the Allies. If we are obliged to rely upon our own efforts alone, as will probably be the case in any future emergency, our failure to recognize the paramount importance of the ordnance problem will result in national disaster. What we need is a completely balanced program for national defense, with the Army paying proper attention to munition power as well as man power. Rifles without men to use them would be a needless waste of money, but men without rifles would involve a ghastly sacrifice of thousands of brave young lives.

As conditions are today our program of national defense is critically out of balance. We look to you military leaders of tomorrow to give your thought and bend your energies to the solution of the ordnance problem—the crux of national defense.

Imagine Production Without Engineering

By HAROLD V. COES,[1] CHICAGO, ILL.

IT IS A FAR CRY from the old handcraft days in the early factory period to the position occupied by modern industry in this country today. Leaving out of consideration all other factors except engineering and modern science, we find the coördination and coöperation of the scientist, the engineer, and the business man play a very substantial part in this development.

Modern organization, modern equipment, modern processes and methods have been brought to their present high state of efficiency mainly by the application of principles and laws from all the sciences. In this the engineer and engineering have played a prominent part.

The greatest step in the history of human advancement was the establishment less than a century ago of the so-called factory system in England, and the accompanying period known as the Industrial Revolution.

This movement, the beginning of modern civilization, consisted essentially of organized and specialized production of manufactured commodities, and was based upon and particularly characterized by extensive mechanical power.

A second great step was the development on a comprehensive scale of transportation facilities, railroads and steamship lines—an essential condition to a large industrial system, since it freed the factories from close local limitations as regarded supply of raw materials, supply of fuel for power, and distribution of manufactured products.

Then came the great electrical inventions, a further subdivision of labor, more power available for operating, with more and more production, lower costs, wider markets, larger plants, continuous production, and, in fact, mass production.

It was the demand for agricultural machines, telephones, motors, and automobiles, steel beams, steel rails, etc. that brought about huge aggregations of men, materials, and money to initiate mass production. Imagine a Fordless, motorless, lampless, telephoneless age, and you can then gage in a way what we owe to science, engineering, and financing.

As more and more demands were made upon the factories' resources by the consuming public, as new developments of science and the application of them by the engineer to industry were made, we rapidly got away from the one-man type of organization and a new set of conditions had to be faced. Organization problems became apparent, which led to a study of the methods used in developing great armies by great military leaders; the functions of line and staff, the army means of research, the study of the railroads' methods of despatch—all these were carefully studied by the engineer with a view to their application to industry.

Wise Leadership

Mr. Alford[2] states that wise leadership is more essential to successful operation than extensive organization or perfect equipment. This law has long been recognized in military affairs, having been successfully stated by one of Napoleon's historians as—"Wise direction is of more avail than overwhelming numbers; sound strategy, than the most perfect armament."

These facts so plainly recognized in military history have their exact counterpart in manufacturing. The factory and office invariably reflect the manager. His policy and direction are the deciding factors for success or failure in operation. The application of this law replaces the autocratic management methods of driving and forcing by the democratic methods of teaching and training.

In the handling of labor, as restricted immigration began to show its steady influence, we substituted careful and at least semi-scientific selection of operators vs. personal preference and lack of

[1] Vice-President and General Manager, Belden Manufacturing Company. Vice-President, A.S.M.E.

Presented at the American Management Association's Production Executives' Conference, Detroit, April, 1927. Abridged.

[2] Laws of Manufacturing Management, by L. P. Alford. Trans. A.S.M.E., vol. 48 (1926), p. 393.

method. In this work, psychology, medicine, and the kindred sciences have been drawn on to aid management.

It has been necessary to obtain standards and means for the measurement of effort, the determination of skill, the reward for effort. In the study of labor for labor rewards we have the pioneer work of such men as Taylor, Emerson, Gantt, Barth, Hathaway, Gilbreth, and Halsey, and from their groundwork we have evolved from straight day work, task and bonus, premium systems, straight piece work, to the more modern methods of group bonus or units for determining comparative man-hour productivity.

In materials the engineer has prescribed definite specifications, tests, receiving inspection codes, means of determination of process inspection, finished inspection, means for the control of production, control of inventories, and of production centers.

INCREASING THE PRODUCT

In equipment, as said before, the intensive development of the past ten years has brought about extreme mechanization of industry. The study of arrangement of equipment, proper flow of materials, reduction of materials handling to a minimum, the substitution of materials-handling equipment for human effort, development of single-purpose equipment, intelligent control of maintenance, the transfer of the skill of the operator to the machine, and the substitution of more and more automatic equipment has increased the product per operator manifold.

In its present phase of industrial development, emphasis is laid on operating methods, the studies of fundamental principles and laws of management. Improved communication, greater extension and generation of electrical power, standardized production and interchangeable parts, perfection of organization, the adoption of the army staff idea, careful consideration of plant location and plant layout, the adoption of budgets, scientific inventory control, despatching and scheduling, scientific determination of production lots—and, in fact, the application of mathematics to economic principles and laws by the engineer and the economist are the outstanding factors of the present phase of industrial development.

In order to obtain a perspective of what all this means, Mr. Alexander of the National Conference Board recently presented some statistics bearing on this subject which are of interest.

In 1900 our national wealth was eighty-eight billion dollars. In 1925 it was three hundred and fifty-five billion dollars, or an increase per capita from $1165 to $3079. Our national income increased from eighteen billion to seventy billion dollars, or per capita from $236 to $593. It is estimated that our income in 1926 exceeds the wealth of most European countries, something that almost staggers imagination.

This is the result of productive accomplishment, careful coördination of labor, capital, and service to the public by management, and in this the engineer has made outstanding contributions. Our average annual worker's earnings have been raised from $480 to $1485.

In 1923 there were required in manufacturing industries as a whole 13 per cent less power, 25 per cent fewer wage earners, and 17 per cent less management personnel than in 1914. In other words, better integration of power, labor, equipment, management, and administration.

Mr. Alexander says: "Immigration restriction has led or will lead to the elimination of most of the unskilled labor in our industries and correspondingly put an additional premium upon the use of mechanical power and power machinery, and of more efficient production methods. It has likewise helped to raise wage levels and so to increase domestic-consumer purchasing power."

Professor Ely, of the Carnegie Institution of Technology, says that the skill of man has been transferred into the machines. In a shoe factory there is not a man who can make a pair of shoes. The shoemaker is merely a machine attendant. The consequence of all this is a change in society from top to bottom.

Some labor-saving machines may at first degrade labor, yet in actual production give in such abundance and so cheaply that all classes, including the laborer, share in the benefit. Never in history have wealth and comfort been so widespread.

The modern engineer is the one factor in our civilization which no other civilization has possessed. We differ from the rest in the widespread knowledge, the binding together of civilized people by railroads, telephone, telegraph, radio, the greater wealth in the world and the more uniform distribution of it.

Mr. Thomas T. Reed, writing in a recent issue of the *Atlantic Monthly*, says: "Admitting that the things that everybody wants are the result of work, how can we get results from the least work?" There are three evident things to do: (1) Direct work so that it does away with the necessity for repeated work. (2) Analyze work and its products so as to eliminate everything that does not aid in attaining the desired result. (3) The multiplying of work. The third is by far the most important, for all human experience indicates that a man cannot do enough work in a year to afford him much comfort unless he is able to multiply his work in this way.

The comparative output of work per person in the various countries of the world, in terms of China as unity, are:

China	1	Australia	8
British India	1¼	Czechoslovakia	9
Russia	2½	Germany	12
Italy	2¾	Belgium	16
Japan	3½	Great Britain	18
Poland	6	Canada	20
Holland	7	United States	30
France	8¼		

On this basis, although we think of China as a country having nearly four times as many people as the United States, the United States has the equivalent of many times the number of effective workers there are in China. In short, the United States may be thought of as a country in which the work being done is equivalent to the work that could be done by ten times as many people as there are in China, or almost forty times as many as there are in the United States, if the Chinese equivalent of our rate of production were used.

Each person in the United States has 35 invisible slaves working for him. The result is, the per capita output of work in this country is so much larger than the output of work in any other country that the subsequent divisible wealth per capita is very much larger.

The present significant trend, then, is toward scientific control through simplified but adequate means, scientific means to reward, the rapid extension of auxiliary devices and aids, emancipating man as a beast of burden, the mechanization of industry, with labor as the controlling means rather than the means itself.

However, there is one great danger to avoid, and that is the mistaking of the form, type, and means of management, be it in production or in any other phase of industry, for managerial skill and leadership. We must not try to force our businesses, our organizations, into a straight jacket. We must beware of singling out some phase of management technique, stressing this to the exclusion of all others—as has been done many times in the past—and thus throwing a whole plan out of balance.

The rapidity with which invention succeeds invention, discovery piles on discovery, production method supplants production method, places a greater burden on management with the injunction that we shall keep our minds open, our forces mobile, our production methods and equipment flexible; for the reigning article in public favor today may, by invention or discovery, or perfection of previously overlooked details, be eclipsed tomorrow.

One of the outstanding characteristics of American industry is its adaptability to shifting and sometimes rapidly changing conditions. Our English cousins marvel at this, and stand entranced with the way we scrap what appears to be perfectly good equipment, methods, or even plants for the sake of increased production and lower costs. They fail to realize that readiness of the financiers to accept the engineers' substitution of best for better, the workers' acceptance of the newer method or increased-production plan for the old, managements' acceptance of both, and the coördination of all, is the principal reason for our outstanding success as an industrial nation, and for the tremendous creation of wealth and its rapid distribution over an ever-increasing area.

For much of this we are deeply indebted to the engineer.

To do this, management is drawing on all sciences, all arts, for aids, methods, devices, laws, principles, and regulatory means, so as to obtain greater and still greater production per operator, per machine, per unit of plant, with lower cost, higher rewards to labor and capital, lower prices to the consumer, with the further distribution of wealth and comfort and greater leisure for the pursuit of the cultural side of our natures as the ultimate goal.

Machine Parts

Discussions of Recent Papers on Advantages of Arc-Welded Steel Parts Over Cast Iron or Riveted Parts, and on Hysteresis in Mechanical Springs

TWO PAPERS[1] dealing with the above-mentioned subjects were presented at the Machine Shop Practice Session of the A.S.M.E. Spring Meeting, held at White Sulphur Springs, W. Va., on May 23 to 26. In the first of these papers, the author, Mr. Wood, pointed out that, mechanically, hysteresis, or the lag of observed effects behind their causes, had not been considered as extensively as in electrical design. Springs, and spring systems in particular, were shown by him to be associated with physical hysteresis of three characteristic types: mechanical, hypo-elastic, and hyper-elastic, the former being shown to be important from the standpoint of automotive riding quality. Mechanical hysteresis, the author stated, is caused by external agencies, while both hypo-elastic and hyper-elastic hysteresis are caused by the internal behavior of crystalline structures. Hypo-elastic hysteresis is due to an internal friction of the solid type, presumably at the grain boundaries, while hyper-elastic hysteresis is due to slip or plastic flow and hence has a characteristic time factor. The concept of hypo-elastic and hyper-elastic energies with their corresponding hysteresis effects, the author said, would enable a better understanding of certain physical properties of metals, particularly those important to mechanical springs. Although, according to the author, elastic-hysteresis effects are of a much lower order than mechanical-hysteresis effects, they are sufficiently large to be given serious consideration in the design of measuring devices.

In the second paper the author, Mr. Lincoln, set forth the advantages of arc-welded steel parts over those of cast-iron or riveted construction, pointed out the savings in cost effected by replacing iron castings with arc-welded steel parts, and showed the inconsistency of permitting arc welding in superheaters and steam piping while forbidding its use in boiler construction.

The two papers were the subject of considerable discussion, both written and oral, the substance of which appears below.

Hysteresis Relative to the Operation of Mechanical Springs

THE first two pages in which the "philosophical" hysteresis loop is discussed, although perhaps correct as a piece of abstract reasoning, are likely to confuse the reader who naturally tries to apply them to the facts of hysteresis as he knows them.[2] A double hysteresis loop, like that of Fig. 1 for instance, has never actually been observed.

The loop of Fig. 4 is correct for the first half of it, but the second half does not appear to be possible from the mechanical system as shown. A complete periodic motion of this system fails to give the complete loop.

The loop of Fig. 5 to represent the mechanical system shown should have rectangular notches in the left upper and right lower corners instead of the smooth curves as given. The author, however, evidently intends this loop to represent a composite system rather than the simple one in the illustration. Nevertheless, in the writer's opinion, for the sake of clearness the loop *a* of Fig. 5 and the mechanical system *b* should exactly correspond.

Fig. 7(*b*) shows ahysteres is loop never realized in practice and out of place in the discussion. The writer is of the opinion that plastic strain is not a true viscous action where the frictional force is proportional to strain velocity, as implied by the author in his discussion of Fig. 12, for instance. Satisfactory experimental results on this point are wanting.

While, in the writer's opinion, too much is left to the imagination, nevertheless the paper is important as a pioneer piece of work in a difficult field.

MR. WOOD gives a metaphysical reason for the *a priori* necessity of hysteresis, but it does not seem to the writer that his explanation of delay between cause and effect is in complete accord with fundamental mechanical concepts.[3] Newton's Third Law, that action and reaction are equal and opposite, implies simultaneity and compels us to regard the ideas of "cause" and "effect" as interchangeable. For instance, if a ball be thrown against a wall, we may regard the deceleration of the ball as the "cause" and the force on the wall as the "effect," or vice versa.

If we examine this illustration more closely, taking into consideration elastic and inertia effects but ignoring friction, we shall find by applying the laws of motion and elasticity to each element of ball and wall, that there *is* a time difference between wall pressure and acceleration of the ball center, because of the finite time of propagation of elastic waves; and, furthermore, this time difference is accompanied by a dissipation of energy in the form of mechanical waves. But this is not hysteresis as we now conceive it. Statical hysteresis is independent of the velocity of deformation, plastic hysteresis appears at low velocities, but elastic-wave dissipation appears in practice only at high rates of deformation such as occur in impact.

The term "lag" ordinarily implies simply a *time* difference, and in that sense is not always applicable to the phenomena under consideration. For it is only in hysteresis of the viscous type that a true time lag occurs; in the pure solid-friction type, if the term "lag" is used at all, it must be regarded as a *displacement* difference, since it is explicitly independent of the time. Any confusion may be eliminated, however, by generalizing the term "lag" to include displacement—lag or *space lag* as well as time lag.

Statical hysteresis, although of the space-lag type, causes a phase lag in cyclical phenomena which resembles a true time lag. For example, in the experiments of Kimball and Lovell cited by Mr. Wood, the maximum deflection of the rod, i.e., the maximum fiber stretch or compression, occurs later in the cycle than the maximum stress due to the applied load. Moreover, it is probable that in nature the two types of hysteresis do not occur in the pure form, but always more or less mixed. It is all the more important, therefore, to distinguish between true time-lag and space-lag effects.

Mr. Wood's use of the words "negative hysteresis" as applied to loops of displacement in the negative direction may meet with some objection because positive hysteresis has been associated with energy absorption and negative hysteresis with energy emission. The terms "hypo-elastic" and "hyper-elastic" are clear and descriptive in themselves, but if they are to be used in a strict sense, they should not be taken as synonymous with statical and viscous hysteresis, respectively. For example, a mild-steel specimen immediately after a moderate overstrain has no definable proportional limit, and therefore has no hypo-elastic hysteresis in the strict sense; yet for subsequent deformations within that overstrain its hysteresis is mainly of the statical type, and abnormally large until the specimen "recovers."

Hysteresis of the pure viscous type cannot be specified without specifying the force cycle. If this cycle is simple harmonic, the resulting hysteresis loops will be elliptical and will not have the sharp corners shown in Mr. Wood's Fig. 4. This can readily be seen from the strict mathematical analogy of an alternating-current circuit having resistance and capacity. If the impressed e.m.f. is simple harmonic, the electric displacement or charge will also be simple harmonic, but out of phase with the e.m.f.; and it is well known that the resulting curve between voltage and charge is an ellipse.

[1] Hysteresis Relative to the Operation of Mechanical Springs, by Joseph Kaye Wood, Consulting Engineer, New York, N. Y.; and Arc Welding, by J. F. Lincoln, President Lincoln Electric Co., Cleveland, Ohio; published in MECHANICAL ENGINEERING, Mid-May, 1927, pp. 561 and 558, respectively.

[2] From discussion by A. L. Kimball, Jr., Research Engineer, General Electric Co., Schenectady, N. Y. Assoc. A.S.M.E.

[3] From discussion by B. Liebowitz, Jackson Heights, L. I., N. Y. Mem. A.S.M.E.

If sharp corners appear in a hysteresis loop obtained under smooth cyclical conditions, then hysteresis of the statical type must be present.

Solid friction involves an abrupt change or discontinuity every time the direction of motion changes. For that reason it is awkward to handle mathematically, hence mathematical writers have often assumed hysteresis to be viscous merely for analytical purposes.

The actual formation of hysteresis loops is but little understood at present. It will readily be seen that if a specimen starts from zero stress and zero strain, the first loop must be different from the second, because the first loop passes through the origin. Referring to Mr. Wood's Fig. 9, there is no reason to expect that the specimen will jump in one cycle from the curve passing through the origin to the loop $+A+D-A-D$. As a matter of fact, it takes a number of cycles for the loop to assume a more or less invariable form, when the specimen is said to be in the "cyclical state." But even then, the loop may go on changing very slowly; in a fatigue test under moderate stress the loop may gradually increase in area until a final steady value is reached; under larger stresses the loop may actually *decrease* in area before it reaches its stable form. It follows that when a specimen has attained the cyclical state and the stress cycle is then changed, relatively large temporary changes in the hysteresis loop may take place before the specimen settles down to its new steady state. These "transients," which may have a very important bearing on fatigue phenomena, are overlooked at present, since practically all fatigue tests are made under steady cyclical conditions throughout. It is submitted that investigation of such "transients" may lead to important new results.

FIG. 1 GENERAL SHAPE OF CREEP-TIME CURVE

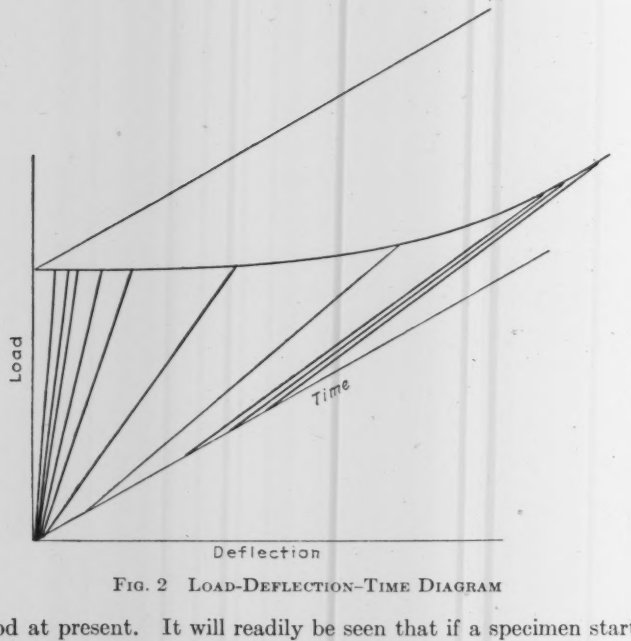


FIG. 2 LOAD-DEFLECTION-TIME DIAGRAM

THAT part of Mr. Wood's paper which deals with hypo-elastic hysteresis is of particular interest to the makers of fine measuring instruments.[4] Springs are daily coming into more general use for measuring time, weight, pressure, and force as well as for regulating the action of delicate machinery. Experiments on springs may have their greatest value, however, when they are regarded as very useful test specimens in studying the laws pertaining to metals in general.

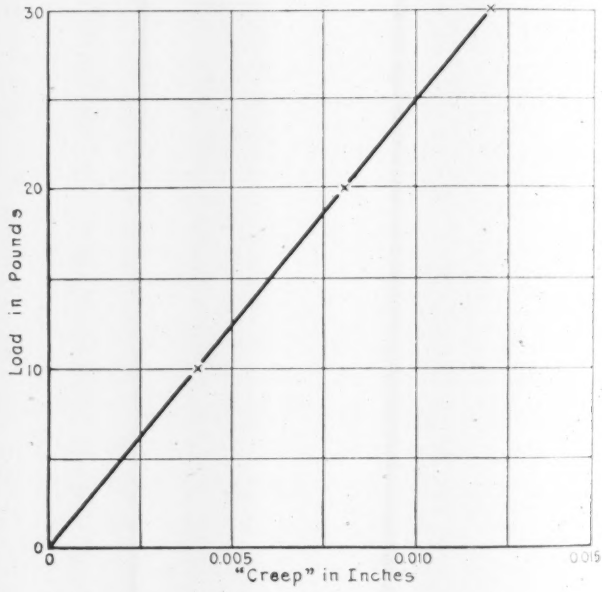


FIG. 3 CREEP IN 24 HOURS ON THREE SETS OF SPRINGS AT VARIOUS LOADINGS

In experiments carried on by the writers it was found desirable in the study of load-deflection relations in materials to give full recognition to the following well-known but frequently neglected facts: (*a*) For a given specimen at a given temperature there is a particular load value below which the metal under a constant load will continue to deform at a gradually decreasing rate, and this deformation approaches a well-defined limit.

Fig. 1 illustrates this point, showing the general shape of the creep-time curve as observed by various investigators of creep in tensile specimens, as well as representing the results of tests on springs.

(*b*) No load-deflection diagram can be represented by a line lying in one plane, and when this is attempted the usual result is an intersection of the time–load-deflection diagram, a warped surface, with a plane perpendicular to the time axis, and intersecting it at a point arbitrarily selected.

Fig. 2 shows the load-deflection–time diagram of a material as a warped surface, and indicates the futility of attempting an explanation of hysteresis by the use of a bi-dimensional load-deflection diagram chosen at random along the time axis. If such a diagram were selected at $t = 0$, the load-deflection diagram would result in a straight line coinciding with the load axis and the deflection would be zero for all values of the load. The absurdity of treating such

[4] From discussion by Stanley Myers, Engineer, John Chatillon & Sons, New York, N. Y., and J. W. Rockefeller, Jr., Engineer, John Chatillon & Sons, New York, N. Y. Jun. A.S.M.E.

a diagram as representing the load-deflection relations of the material is immediately apparent.

Fig. 3 shows the load-creep relations in 24 hours in tests made on three sets of similar springs. The time of creep was measured from a point after the springs had come to apparent rest (10 min. after loading). It will be noted that the increased deflection at this point is proportional to the load, and that the load-deflection diagram of 24 hours earlier has simply swung through a small angle in the direction of the deflection axis.

The behavior of metal under loading as observed in numerous creep and hysteresis tests on springs may best be described by analogy. Fig. 4 shows a combination of two springs connected in series; a plunger between the two springs is free to move in a stationary cylinder containing a fluid of high viscosity, but can move only as fast as the fluid forced through the clearance between its outer edge and the inside of the stationary container will permit. It is apparent that the position taken any time by the plunger will depend upon the unbalanced force acting upon it and the time, i.e., its rate of motion will be governed by the load put upon the lower spring. Consider the combination as a unit. The second position of the combination shows its position shortly after a load has been imposed. The primary elastic deformation (i.e., the deformation of the lower spring) has already been effected. The secondary elastic deformation (that of the upper spring) has just started and will continue under a gradually decreasing unbalanced force, approaching as a limit the third position shown in the illustration.

It will be observed that it is possible for the lower spring vibrating harmonically to be stretched at times to a greater length than its final one in the third position, before the upper spring has been deflected to the length shown in that position.

It is also to be noted that if a heavier weight is hung on the lower spring, the unbalanced force acting on the plunger will be correspondingly greater and its position after an equal time interval will be lower. Assume this additional weight to be large enough to move the plunger to a point between those shown in the second and third positions of the combination, but to be removed immediately the given time interval has elapsed. In this case the unbalanced force on the plunger will still be in a downward direction but at a more advanced point under the same load, i.e., the loading and unloading curves of the combination will not coincide. Assume that the only difference in the gradual displacement of the plunger by time and the rapid displacement under a greater applied load is in the effect on the liquid, which in the second case is displaced more rapidly and by a greater force. If we suppose that this effect is to decrease the viscosity of the liquid, then the action of time and force on the combination is similar in every way to the action observed in springs under "creep" and hysteresis tests.

Going back to Fig. 1 and noting that the "creep" approaches a limit, it will be seen that it is possible to determine such a set of limits for various loads. If these deflection limits are plotted against the corresponding loads; the result will be the intersection of the time-load-deflection diagram with a plane perpendicular to the axis at the point t.

If this line is considered as representing the time–load-deflection rate of the material, the action of creep and hysteresis may be seen to have in common the tendency to bring coincidence of the apparent and true load-deflection rates.

The dash-pot analogy outlined above is of interest in view of the results obtained on spring tests, a suminary of a few of which follows:

Springs were especially prepared to give a large hypo-elastic hysteresis loop and showed a difference of 0.004 in. at 10 lb. load on a short time cycle between 0 and 30 lb.

These springs were loaded for 24 hours with 10 lb., after which they were put through the remainder of the cycle. The difference in loading and unloading in this case was less than 0.001 in. on 10 lb.

From data taken on hysteresis loops a distinct relation was found to exist between the percentage of increased deflection, or

$$\left(\frac{\text{hysteresis}}{\text{initial deflection}}\right),$$ and the percentage of overstress, or

$$\left(\frac{\text{maximum load of cycle less load}}{\text{load}}\right).$$

These data taken from spring tests where the stress may be considered torsional were checked with data on flexure tests, and the percentage increased deflection plotted against percentage overstress showed a distinct relationship in this case as in the case of torsional stressing.

In all tests made the results indicated that for the study of both hypo-elastic hysteresis and "creep" the proper starting point is a load-deflection diagram so constructed that the abscissa represents the limit of deflection rather than the deflection at any given time. They point also to the probability of fundamental similiarity in "creep" and hypo-elastic hysteresis.

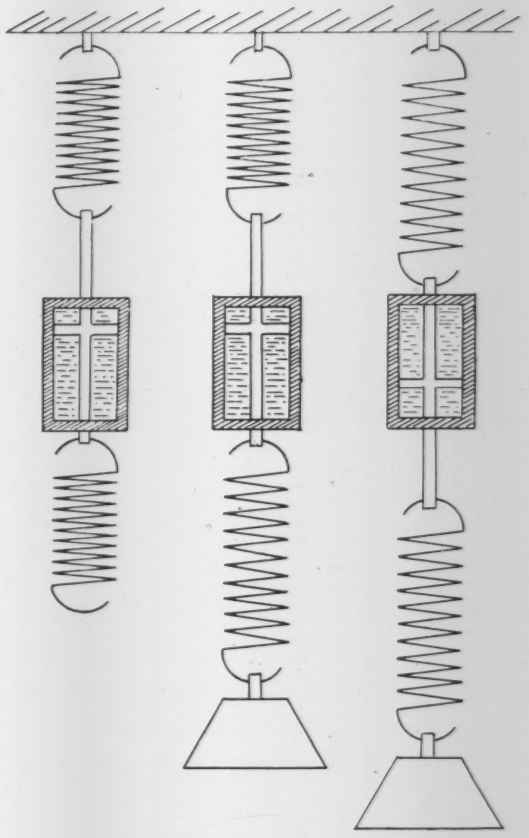


FIG. 4 SPRINGS CONNECTED IN SERIES THROUGH PLUNGER WORKING IN A STATIONARY CYLINDER FILLED WITH HIGHLY VISCOUS LIQUID

THE writer greatly questions whether there is any real difference in character between hypo-elastic and hyper-elastic energy.[5] Let us consider what actually happens during the loading of a material. As the loading increases, the atoms are pushed infinitesimally closer together or pulled slightly further apart, and elastic change in length occurs. Presently, at some one spot where a flaw exists, or where initial internal stresses are present, or where a grain is so oriented as to be weak in shear, the shearing elastic limit is locally exceeded and shearing slip occurs, resulting in absorption of plastic energy and in a permanent change of length. The volume affected may be only one-millionth of the total volume of the piece, but rigorously, the elastic limit has been exceeded. With increasing loading, more and more local spots are affected, as slip occurs on one shear plane after another throughout the material. Where these local slips are helped on by initial internal stresses present in surrounding grains, their effect is mainly to relieve these stresses, and a hysteresis loop may not be caused. Where the slip occurs in a grain which due to its orientation or to its character is weaker than the surrounding grains, the effect is to throw an additional load on these surrounding grains, which thereby become more highly stressed. If the load does not go too high, it may be that these grains will not fail. On removing the load, it may be that they may even be able to pull the weak grain back

[5] From discussion by Mortimer F. Sayre, Associate Professor of Applied Mechanics, Union College, Schenectady, N. Y. Mem. A.S.M.E.

to its original shape before the load has dropped back to zero, resulting in a pseudo-elastic hysteresis loop; i.e., one going above the true proportional limit of the material, but nevertheless showing no apparent permanent set. In other cases the distortion, either in this grain or in other grains, will have gone so far that a permanent set will remain after the removal of the load.

In other words, plastic changes are localized phenomena, which directly affect only the material in the immediate neighborhood of the slip plane. The minute this localized stretch becomes great enough to show up on our stress-strain curve, the apparent proportional limit is passed; but that fact in no way changes the character of the elastic energy being stored up in the balance of the specimen. In fact, I very greatly question whether there is any real difference in character between the hypo- and hyper-elastic energies at the slip planes themselves. There is certainly nothing which justifies us in selecting arbitrarily some point as a virgin elastic limit, and then stating, as indicated in Fig. 14 of the paper, that above that point (P_E) the excess elastic energy developed (i.e., the hyper-elastic energy) will be practically all lost in hysteresis on releasing the load.

This is a rather vital factor to the spring manufacturer. The rise in proportional limit due to the cold working which a material receives during a tensile test is essentially no different from the increase in the same quantity due to any other form of cold working; and the statement just quoted tacitly implies that the useful resilience of cold-rolled bronze or of cold-drawn copper or steel wire is determined by the proportional limit before the cold working, and has not been increased by the process. This is not the only illustration which could be given. As a matter of fact, there is scarcely a spring made where the working unit stresses do not go beyond the true proportional limit of the material, and certainly all clock and watch main springs would be ruled from service.

Certain other points might well be noticed. In Fig. 7(*b*) the hysteresis loop should apparently be a single oval, extending from 1 to 3, rather than a figure eight. In the last paragraph of page 565, the statement, "In Fig. 10 (*f*) the uniform increments of force *a*1, 12, 23, and 3*c* cause the logarithmic increase in deformation of *b*1, 12, 23, and 3*V* due to the previously stated fact that in plastic flow the rate of deformation beyond P_{E1} (load of initial flow) varies directly as the increase in force," might well be questioned. Is this not rather due to the fact that as the load increases, progressively greater numbers of slip planes come into action?

Referring to the next to the last paragraph of page 566, attention should be called to the fact that "yield point" is characteristic only of stress-strain curves for steel or wrought iron. Stress-strain curves for pure copper, pure aluminum, or pure zinc show no such dip and rise. In fact, the purer they are, the less evidence there seems to be for the existence in these metals even of a true proportional limit, in the rigorously exact sense.

The most important criticism is the initial one, directed against the statement that "hyper-elastic energy does not represent a gain since it is practically all absorbed in the hyper-elastic loop." A truer explanation of what actually occurs is given in the author's Fig. 18. Here, for complete cycles of stress (from positive to equivalent negative values), the proportional limit in the positive direction is shown as being increased by overstrain, with a large increase in the positive resilience. On reversing the load, the apparent proportional limit in the opposite direction will now be found to have been reduced by much the same amount as the first was increased, so that the net elastic range is not increased. Hysteresis loops M, M_1, and M_2 are the same in area, rather than different, as in Fig. 17. In actual size, these loops are rather too large in proportion to the amount of resilient energy actually available, judging from my own experience.

GEORGE M. EATON,[6] discussing the paper orally, said that there was one practical point he wished to bring up in connection with a difficulty which the designer would encounter when he had his hysteresis arising from a source of external application. In one of the figures employed by the author, friction had evidently been considered as a constant quantity in repose and in motion. Unfortunately that was a very difficult thing to secure. Mr. Eaton thought the point sufficiently important to bring up because he had learned through costly experience. The point was that there was a storage of energy in overcoming the friction of repose when the friction of repose dropped to the friction of motion. There was a release of energy, a wave being set up and if, unfortunately, the conditions became critical, then resonance, with its usual destructive results, was encountered.

[6] Engineer, Molybdenum Corporation of America, Pittsburgh, Pa. Mem. A.S.M.E.

AUTHOR'S CLOSURE

IT IS gratifying to know that the publication of this paper has resulted in considerable discussion which reveals a lack of uniformity in the various conceptions of hysteresis and the use of terms. The author accordingly recommends that a symposium on this important subject be held one year hence under the auspices of the Special A.S.M.E. Research Committee on Mechanical Springs for the purpose of a more thorough discussion and classification of terms.

In view of the preliminary remarks made by Messrs. Kimball and Liebowitz, the author would like to restate that the purpose of the first two pages was merely to give a fundamental understanding of hysteresis and to define all of its terms. If the field of metaphysics has been trespassed upon lightly, the author begs his readers not to let this influence their study of the main and more important part of the paper. Mr. Kimball apparently was so influenced, as he did not touch upon the physico-metallurgical phase of the paper, much of which is based upon recent researches. On the other hand, Mr. Liebowitz was inclined to discuss the brief metaphysical section, but such a discussion at this time would probably not amount to any more than a mere play on the meaning of words and an exchange of personal beliefs. Fortunately however, Mr. Liebowitz's metaphysical discussion led him to offer very constructive suggestions as regards the definition and classification of terms. For example, the allocation of the general term "lag" to signify either "space lag" or "time lag" should be practical with the qualification, however, that these terms are merely descriptive of the nature of the lag. In experimental practice lag is measured in displacement units, although it may be either a "time" or "space" lag. The significant point is that hysteresis having three principal components, namely, time, force, and displacement, lag must be measured with respect to time and force. Where the speed of testing is excessively slow with respect to the time phase of lag, the hysteresis loop will be small or may not be obtained at all. Going to the other extreme where the speed of testing is excessively fast with respect to the time phase of lag, then the hysteresis loop will be of a definite or constant size. So-called statical hysteresis in which the period is for all practical purposes infinitely large is of the latter type. It should be noted that solid friction is really the result of a combination of many small elastic and plastic deformations. The foregoing statements may be symbolized approximately as follows:

$$F = kSt^x$$

where F equals the deformation, S, the stress, t the time, k a constant and x an exponent which in statical cases approaches zero and in plastic action equals unity approximately. Mr. Liebowitz' statement that in the pure solid-friction type of hysteresis, lag is explicitly independent of time, is not strictly true, as Mr. Eaton's experimental results have shown.

NOTE: Metaphysically the factor of time cannot be eliminated from the discussion as no absolute case exists within the realm of understanding. This may be in accord with Einstein's theory of relativity, and if so would explain why in Newton's third law of equality of action and reaction or of cause and effect absolute simultaneity should not be implied as Mr. Liebowitz reasons.

In this paper "negative or positive hysteresis" refers to displacements and does not cover areas representing loop energy. Hypo-elastic energy is determined before overstrain takes place, because after overstrain a large portion [*adc* in Fig. 14(*a*)] of hyper-elastic energy is "trapped" which is released upon "recovery" due to, say, immersion in boiling water or higher-temperature treatment.

Regarding Mr. Liebowitz' remarks on the sharp corners shown in Fig. 4, he will find upon reading the paper again that this diagram does not represent a hysteresis loop of the "pure" viscosity type but includes a certain measure of the "statical" type, in which

case he agrees that sharp corners should appear. The author agrees with Mr. Liebowitz' statement concerning Fig. 9, but for the sake of clearness the intermediate stages necessary to produce the cyclic state have been omitted since the purpose of the sketch is only to show the characteristic shape of the viscosity type of hysteresis loop. Finally Mr. Liebowitz' suggestion that the effect of hysteresis transients on fatigue tests be investigated is certainly worthy of consideration.

Referring to Mr. Kimball's other remarks, it must be stated that Fig. 1 is only intended to illustrate the terms as used throughout the paper and not to represent observed phenomena. Unfortunately the origins of the two quadrants of this figure and also of Fig. 7(*b*), were unintentionally made coincident. In neither case is continuity of action or observed phenomena involved. In transcribing Fig. 4 from the author's original notes it was confused with Fig. 12. Fig. 4(*b*) was intended to appear as shown in Fig. 5, herewith, which will give the complete loop as shown in Fig. 4(*c*) of the paper.

Mr. Kimball's desire that the statistical effect of an aggregate of different crystals which the author states is the reason for cutting off the rectangular notches in the left upper and right lower corners of Fig. 5(*a*) of the paper, and forming the loop shown, should be incorporated in the mechanical system 5 (*b*) is impractical. Neither should it be necessary to break up the composite diagram, showing how the loop is obtained, into step-by-step diagrams since the single diagram as shown is anything but complicated.

In stating his opinion that plastic strain is not a true viscous action Mr. Kimball could be easily more correct because the

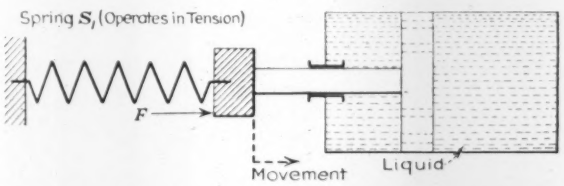


FIG. 5 CORRECTED FORM OF FIG. 4(*b*) OF PAPER

exponent x in the general deformation law stated above may be slightly less or greater than unity. The author holds the general opinion that plastic strain velocity depends on the value of the shearing force carrying slip (the author did not call this a "frictional force" as Mr. Kimball states). Experimental results are wanting only on the exact value of the exponent.

Professor Sayre in questioning whether there is any real difference in character between hypo-elastic and hyper-elastic energies, creates an issue of his own. The author did not state that there is any such difference, but simply assigned the prefix "hypo" to that portion of elastic action which does not occur coincidently with plastic action and the prefix "hyper" to that which does occur coincidently with plastic action. Whether or not plastic action or slip occurs locally does not affect the correct usage of the terms as defined. Wherever the term "true" proportional limit is used, it is intended to apply to the total volume of metal under consideration whether it be a single crystal or an aggregate of crystals. Therefore the first three paragraphs of Professor Sayre's discussion with the exception of his remarks on Fig. 14 are based on the incorrect premise that the author differentiated between the character of hypo- and hyper-elastic energy.

In regard to Fig. 14, the author would refer Professor Sayre to the experimental results of W. E. Dalby, published in the Proceedings of the Royal Society of London, vol. 86A, 1911–1912.

The author's comment concerning Fig. 7 (*b*) is given previously in this closure. Professor Sayre's question regarding Fig. 10 (*f*) is one which may be answered by himself by answering the following analogous question: For a given head of water, is the velocity of flow affected by the volume of discharge?

In the next paragraph of this discussion, the absence of yield points in zinc and similar metals may be explained by the relatively large plastic phase characteristic of these metals which tends to dampen the sudden overload illustrated in Fig. 12. Finally in Professor Sayre's concluding paragraph he apparently fails to note that the repetitions of stress in Fig. 17 are limited in each cycle to the newly created proportional limits, whereas in Fig. 18 they are held within numerically equal stress limits. As to the size of loops, no attempt was made to preserve true proportions since this matter was not an involved issue.

The discussion by Messrs. Myers and Rockefeller represents a worthy contribution since it gives the detailed results of actual experiments in connection with the hypo-elastic phase of the subject.

Mr. Eaton rightly calls attention to the oscillatory transition of the friction of motion from the friction of repose. However, allowance for this phenomenon would only slightly affect the extreme ends of the loop. Once motion is effected, the friction would be constant, as the author has shown.

Arc Welding

ARC WELDING joins the pieces to be connected by means of fused metal and the resulting structure is essentially a cast structure, and in a more rigid interpretation of the term, "arc welding" is not welding at all.[7] In the words of John Edward Stead:

> When the boundary of the crystal is coincident with the juxtaposed plane surfaces it is evidence of non-welding, which is equivalent to saying that *unless the crystals become common to the two pieces there is no welding.*

By arc welding the crystals cannot "become common to the two pieces" because all macroetchings of samples taken from fusion-welded structures show a grain growth at the weld, and inasmuch as this grain growth at the fused portion differs from the grain of the parts to be joined, there is a reduced homogeneity of the structure and a reduced endurance limit.

This streak of cast metal that is fused in to join the pieces has not been subjected to the refining influences of mechanical working and cannot be controlled to the same extent that a casting made in a foundry can be controlled, with the result that it is not a good casting.

The melted metal is exposed to the air with the chance of being oxidized or of absorbing gases, and all too often this fused portion is porous, including slag and oxides.

To state that "the weld is as strong as the plates joined" is entirely misleading, because most mechanical structures demand something more than high ultimate tensile strength for their success, and, as stated above, weld metal is deficient in ductility as a result of its coarse crystalline structure.

The records are filled with failures of all sorts of mechanical structures, pressure tanks, etc. that have either been built by fusion welding or repaired by fusion welding, with failures resulting primarily due to this coarse granular structure in or near the weld.

The last report of A. G. Pack, Chief Boiler Inspector of the Interstate Commerce Commission, shows numerous such failures on locomotives and Mr. Pack has made the statement that—

> It is my opinion that success with fusion welding consists more largely in restricting its application so that doubtful or dangerous jobs will not be attempted, rather than on the technique of the operation, though the latter is by no means of minor importance.

The Bureau of Standards in one of its publications makes the statement:

> A fusion weld is fundamentally different from all other types in that the metal of the weld is essentially a casting. The arc-fusion weld has characteristics quite different from other fusion welds. A preliminary study of a considerable number of specimens welded under different conditions confirmed this general opinion concerning arc welds. A knowledge of the properties of the arc-fused metal is fundamental in any study of electric-arc welding.

However, when we revert to true "welding" we find a different story. As the term "welding" implies that the crystals of the adjoining plane surfaces must become common to the two pieces, we must immediately revert to pressure in conjunction with temperature to do "welding," and then we have the familiar process of forge welding.

In forge welding the metal is never brought to a molten condition and no foreign matter is added, so that there is no change in the grain structure at the seam, and the chemical and physical properties of the metal at the seam are not impaired in any way. Actually, the metal in the seam of a forge weld will show better characteristics

[7] From discussion of L. A. Belding, Sales Engineer, American Welding Co., New York, N. Y. Mem. A.S.M.E.

both physically and chemically than the metal of the virgin plate, due to the mechanical working in a plastic condition.

The records of insurance companies, inspection bureaus, and other agencies do not reveal numerous failures of forge-welded equipment, and yet forge welding is one of the oldest arts and was practiced long before fusion welding was ever known.

For uses involving repeated alternate stresses, such as car tanks for tank cars on the railroads and for various high-pressure tanks in our many intricate chemical processes of today, forge welding with its resultant homogeneous structure is the only process that can be successfully used to produce such pressure equipment that is tight when it is finished and will remain tight in use for many long years of service.

ALTHOUGH Mr. Lincoln's paper is one dealing with the substitution of the arc-welded-steel product for the cast product, he has limited himself to cast iron and repeat production to the

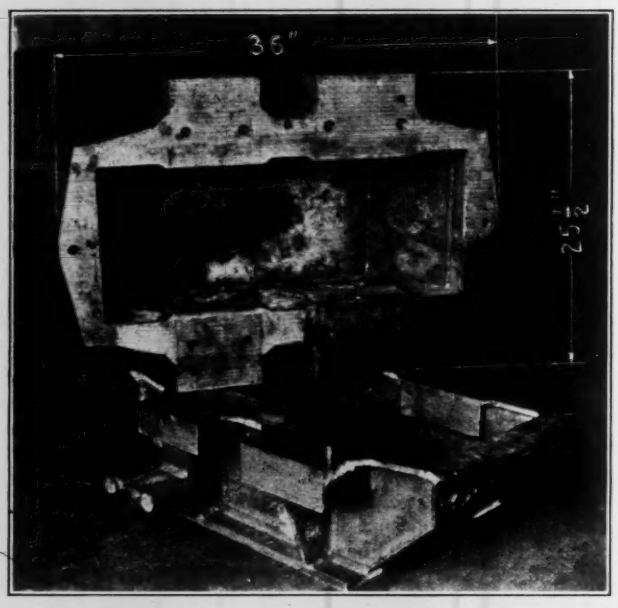


FIG. 6 METAL-ARC-WELDED GEAR CASING

exclusion of cast steel, and to the manufacture of one or a limited number of items.[8]

In many respects the substitution of the welded-steel product for cast steel will effect relatively greater savings than those obtained with the cast-iron product. Again, in numerous industrial concerns, greater savings can be effected by the use of welded steel for the production of one or a limited number of items of the same kind than is the case with repeat production. This is true for both cast iron and cast steel.

In repeat production, pattern cost is a mere fraction of the total cost, whereas, when only one item is cast, the pattern cost may be many times that of the casting. For example, the cost, exclusive of machine work, of the metal-arc-welded steel gear case shown, partly machined, in Fig. 6 (material, labor and 70 per cent overhead), was $182, as compared with an estimated cost of $250 for a similar cast-iron gear case. The pattern cost was estimated at $186 and the casting at $64. The estimate for the casting was figured at $0.085 per pound and an overhead of 70 per cent assumed for the pattern. The cost of this particular casting would have been high, as its walls would have been light and complicated core work would have been necessary.

A completely metal-arc-welded condenser shell for a merchant ship is shown in Fig. 7. In this case a saving in labor, material and overhead of $847 was obtained over a similar cast shell with pattern included, and a saving of $200 over a similar riveted shell. In the construction of a second welded condenser, the welding cost was actually reduced by more than 50 per cent, and should the heads and water chests of these condensers be also constructed of welded steel instead of cast iron, it would be possible to effect even greater savings in cost. The saving in weight of the welded shell (exclusive of heads and water chests) over the cast shell was 50 per cent, and over the riveted shell, 10 per cent. As far as known, these are the first two completely welded condenser shells constructed to date.

The percentage of defects is much higher in steel than in iron castings, and as these defects are frequently not discovered until machining is nearly finished, the financial loss from rejected castings (excluding those castings salvaged by welding) is a serious industrial problem, as it involves not only the loss of the casting but also the machine work with its attendant overhead. Losses from this cause can be wholly eliminated by the use of welded steel.

The unnecessarily long time required in the manufacture of a cast product is also a very serious industrial waste. This time element in the production of steel castings is much greater than for iron castings. Exclusive of the time required to make the pattern, the normal period required by the foundry of the writer's company for making the mold and baking it, pouring the casting, cleaning and annealing, is two weeks. Any one of these operations may require twenty-four hours or more. This time, of course, can be and is materially shortened in cases of emergency, nevertheless it must be borne in mind that the making of a steel casting requires a relatively large amount of time. The time factor in the replacement of castings, in case of a breakdown to machinery, would alone justify an immediate and extensive utilization of welded steel. In shipyards, the replacing of broken or defective castings by similar castings frequently requires a ship to remain tied up for days, with losses due to fixed charges, wages, fuel, and cessation of earning capacity amounting to upward of $1000 a day, and if drydocking is necessary in the replacement, the additional cost of drydockage may reach $1000 or more per day. These losses are not peculiar to ship operation, for similar losses obtain wherever industrial service is interrupted, and welded steel will reduce them to a minimum by making possible immediate replacement.

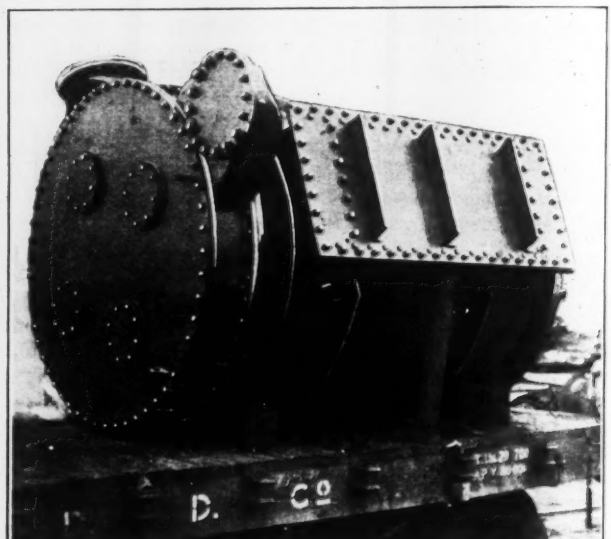


FIG. 7 METAL-ARC-WELDED MAIN CONDENSER 7 FT. 5 IN. IN INSIDE DIAMETER AND 9 FT. 7/8 IN. BETWEEN TUBE SHEETS

A saving in weight can be effected by the substitution of welded steel for castings. Savings in weight, while much greater when welded steel is substituted for cast iron, are not confined to this material. The uniformity of rolled or drawn steel permits the use of thinner material than would be considered if the article were of cast steel. Again, reinforcing ribs can frequently be located to better advantage than is possible with the cast product, and, unlike cast ribs, they do not tend to create shrinkage holes and weak and porous spots. Although saving in weight is not a factor in general machinery design, except as it may affect savings in cost, it is becoming increasingly important not only in naval construction but in merchant ships as well. Due to the decrease in weight secured by the use of welding, castings have been very largely eliminated in aircraft construction.

[8] From discussion of James W. Owens, Director of Welding, Newport News Shipbuilding & Dry Dock Company, Newport News, Va.

While the writer cannot foresee the entire substitution of welded steel for castings, due to the massiveness and complicated contour of many products, nevertheless, assuming that rolled steel of 1¼ in. thickness is the maximum that can in general be utilized at present in this class of work, the yearly industrial savings which may be effected by welding will be enormous.

In conclusion, considerable ingenuity will be required by the designer of the welded-steel product to reduce labor to a minimum. Every endeavor should be made by him to design so as to avoid unnecessary bending and forming of parts and the hot-working of these parts by the blacksmith, and to eliminate as far as possible holes for assembly purposes.

While the paper deals exclusively with arc welding, the designer should avail himself also of other welding processes, namely, resistance, gas, and thermit.

UNDER the heading "advantages of arc-welded steel parts over riveted or cast-iron parts" it is stated in the paper that an arc-welded joint will give the full strength of the original steel.[9] It seems to the writer that many of these claims for full strength of welded steel are based on incomplete premises leading to that same faulty deduction by logic of which a complaint is made in the final paragraphs of the paper under discussion.

Instances of faulty deduction are not wanting when, for example, two plates of steel are welded together and the laboratory testing machine induces fracture not at the joint but along side of it, the conclusion is immediately drawn that the welded joint is as strong as the original steel plate. Or when an explosion occurs, as in the case of that welded brine cooler at the Fleischmann plant in Chicago where the plate was ripped all alongside of the weld, the same surmise is made, whereas in reality the more correct conclusion in each case is that the molecular structure of the steel plate adjacent to the joint has been so badly disturbed by the heat of fusion as to make fracture much more probable along this adjacent strip—of so-called pigeon-wing-blue temper—than at the joint.

The conclusion is amply justified that the plate has been weakened by the arc flame perhaps as much as, and certainly worse than, by a riveted joint. Worse, because no one knows exactly how much weakening has been effected by the welding fusion, whereas every one knows the percentage of full plate strength that a riveted joint has. Even annealing does not fully repair this molecular disability either at the line of fusion or adjacent to it, because it stands to reason that no fused joint or overheated edge can have the 100 per cent resilient strength of steel plate unless that fused metal has also been hammered, squeezed, or rolled like the original plate in the making. The findings of the Bureau of Standards confirm this.

There must be a reason for the preponderance of expert opinion favoring rivet steel for boilers, air receivers, and all equipment where working conditions are extra hazardous. The soundness of this judgment and of the logic by which it is influenced is borne out by published records showing the behavior both of fusion welding and of riveting under conditions of unusual stress, such as in wrecks and explosions where both processes were used on the same locomotive boiler. From reading the reports of the Bureau of Locomotive, Inspection published by the Interstate Commerce Commission the conclusion must inevitably be reached that arc-welding is *not* considered satisfactory on a locomotive boiler, the statement in the paper to the contrary notwithstanding.

By no law of logic may the evidence of riveted-steel satisfaction for stationary boilers as written into the steam-boiler insurance and inspection companies' records be set aside either. The writer knows of at least one case where an oil burner had been left on at night under a riveted steel heating boiler with the steam supply valve inadvertently closed so that all the water soon evaporated out by way of the safety valve. When the janitor returned in the morning the burner was still on, and the boiler at a dull red heat. Thanks to the riveted-steel construction, the boiler was easily reconditioned and put back in service the same day with full consent of the insurance company.

In connection with the subject of fusion welding for piping, the writer would suggest that any engineer who is considering that process for large piping should read of all the difficulties he might dream of encountering in the description of the Mokelumne pipe line where welded joints were to save $4,000,000 in laying the 85-mile line. Welding processes were abandoned and the successful change to riveting was only made after every expedient to overcome expansion and shrinkage difficulties, due to the heat of fusion, had failed.

Reference to a report of Chief Inspector of Bureau of Locomotive Inspection shows that in the last eleven years there have been a total of 563 locomotive firebox crown-sheet failures. The sheets tore in 238 of these instances. In 313 of the 563 failures there were riveted firebox seams, but 84 per cent of these *did not* fail. In 158 of the 563 failures there were welded firebox seams, and 77 per cent of these *did* fail.

Would not logical reasoning lead to the conclusion that in practice it is the riveted seam that is actually stronger, through its reinforcing effect, than the original plate, which also has its original molecular structure intact in riveted construction?

FUSION welding, as a means of joining metals, is thoroughly established in all metal-working industries.[10] It needs no advocate before this body. The author shows, however, a new application of welding, namely, the replacement of relatively small castings made in relatively large quantities by welded structures employing standard steel shapes. Large economies are rather obvious in the case of the substitution of welded steel-plate material for certain forms of large castings. Here the casting cost per pound is high and frequently also the pattern cost because of the small number of castings made from one set of patterns—often only one or two. One large manufacturing company reduced its cost for such parts over one million dollars during the past year by substituting welded construction for castings. But Mr. Lincoln has shown in a very convincing manner the possibilities even where castings are being made on a quantity basis.

This application is one example of what can be accomplished if the design or the construction is changed to permit taking maximum advantage of the use of the welding process. Mechanical engineers should bear in mind that economies resulting from the use of welding are not limited to those due to the mere substitution of the welded joint for some other form of joint. The maximum gains will only be attained when designs and methods of construction are changed so as to take the greatest advantage of the possibilities which welding affords.

In the latter part of his paper the author refers to apparent inconsistencies in safety regulations of different authorities which have to do with welded structures. While the American Welding Society feels that some of the requirements in the A.S.M.E. Boiler Code dealing with welding are much too restrictive, it appreciates the responsibility of the Boiler Code Committee and the position which it must take. This Committee is coöperating with the American Welding Society in a very thorough manner in connection with the efforts of the latter to demonstrate the reasonableness of its contention with respect to these restrictive clauses.

Many of the codes and regulations with which welding comes in contact have been developed gradually over a period of many years. On the other hand, fusion welding has come into use rapidly within a very few years. It is not surprising, therefore, if there are inconsistencies in these codes, particularly in regard to welding. All that the welding fraternity asks is an honest and energetic effort on the part of those responsible for them to give the welding process all the credit to which it is entitled in the light of established evidence, and no more.

THE conservation of human life and limb is a solemn duty not to be influenced by promised economies for any method. If it is a fact that the Interstate Commerse Commission "allows very wide latitude in the use of arc welding on locomotives," the Bureau of Locomotive Inspection might well consider the revision of its codes judging from a study of its annual reports.[11] The fifteenth annual report of the Bureau of Locomotive In-

[9] From discussion by Edward D. Quirke, Advertising Manager, Kewanee Boiler Co., Kewanee, Ill. Mem. A.S.M.E.

[10] From discussion by F. M. Farmer, Chief Engineer, Electrical Testing Laboratories, and President, American Welding Society, New York, N. Y. Mem. A.S.M.E.

[11] From discussion by A. F. Jensen, President, Hanna Engineering Works, Chicago, Ill.

spection covering the fiscal year ending June 30, 1926, lists five accidents in which riveted joints were involved resulting in injuries to seven as compared to eleven accidents involving welded joints with injuries to thirteen. This datum in itself testifies to the superiority and safety of the riveted joint, but more forcibly so when the number of lineal feet of riveted joints in approximately 70,000 locomotives is compared with the limited extent to which welded joints are or have been used.

Permitting the use of fusion welding in the present state of the art in locomotive-firebox and boiler construction and repairs does not appear advisable. It is a recognized fact that serious boiler explosions cannot occur unless the rupture in the boiler is sufficient to suddenly reduce the pressure. Locomotive-boiler explosions are never of sufficient severity to throw the boiler off its frame unless the sheets tear and suddenly release the pressure. During the period July 1, 1915, to June 30, 1926, fusion-welded seams were involved in 28 per cent of the total crown-sheet failures, while 51 per cent of the total persons killed in crown-sheet accidents were killed where fusion-welded seams were involved. Of the riveted seams involved 16.3 per cent failed, while 77.2 per cent of the fusion-welded seams failed under exactly the same conditions. The average number of persons killed per accident in which the riveted seams were involved was 0.77 as compared with an average of 1.16 killed per accident where fusion-welded seams were involved.

Crown-sheet failures are largely the result of overheating due to low water, and nothing will prevent the crown sheet coming down when it has been overheated. However, if a particular method of joining metals will minimize the fatalities and property damage, it should be used. That riveting accomplishes precisely that is evidenced by the record of the Bureau of Locomotive Inspection to which reference has just been made.

The explosion of a riveted boiler built to code requirements due to an inherent defect of either material or workmanship is practically unknown. Contrast this with the numerous failures of welded pressure vessels under normal working pressures due largely to insufficient fusing.

How can we obtain good welds commercially with certainty? Specimens made expressly for test (under test conditions) do not represent a welder's regular output. How can we be assured that the weld is complete and ascertain the magnitude of the initial stresses in the structure which the welding process sets up? What assurance have we of its ductility and the extent to which the metal in the vicinity of the weld has been affected? Until these intangibles no longer exist we must impose implicit confidence in the deliberations and decisions of our code framers.

Riveting is one of the oldest arts and there are no intangibles when considering its application: the strength of a riveted joint can be mathematically predetermined, its efficiency does not depend on the man doing the riveting, and a riveted joint may be inspected and reasonable assurance of its soundness obtained.

The research activities of those interested in advancing the art of welding are most commendable; much more of it is necessary, however, to permit various agencies charged with the safety of life and property to formulate codes or procedure control whereby it may function effectively where welding is to be considered. Too much discretionary latitude on the part of inspectors is not advisable.

The modern laboratory instruments for research in applied mechanics were not available when tests were made which determined the design rules followed today in riveted-joint structures. The unquestioned reliability of millions of riveted joints made to those rules demonstrates that if the tests were crude according to present-day standards the inaccuracies resulted in errors on the safe side. But how much on the safe side? A recent investigation by Commander E. L. Gayhart (C.C.), U.S.N., of the behavior and of the ultimate strength of riveted joints under load disclosed an efficiency of 80 to 85 per cent on gross section for all joints instead of the theoretical value of 76 per cent. This suggests further research of this seemingly unimportant metal pin—the rivet.

This, the greatest building age in history, has been made possible by riveted steel. Approximately 150 rivets are required per ton of structural steel. Bookings of fabricated structural steel have more than doubled in fourteen years, the average monthly bookings in 1925 and 1926 being 218,000 tons. A consumption of more than thirty-two million rivets per month conveys some idea of the rivet's important place in structural-steel fabrication.

Probably one million tons of riveted steel bridges were erected in this country between 1890 and 1900, nearly all of which are still in service, except when too light for increased traffic. On the Pennsylvania R.R., east of Pittsburgh, over 500 bridges built previous to 1897 are still in excellent condition notwithstanding the large increase in loads to which they have been and are subjected. There are seventy thousand linear feet of bridge structures on the Lehigh Valley R.R. (the oldest structure is about sixty years old), and none has been replaced except on account of accident or unduly increased loads. Some of the New York Central and Hudson River Bridges have been in service forty years. Other notable examples are the steel arch ribs of the famous Eads bridge over the Mississippi River at St. Louis which have seen fifty-two years of service, and the trusses of the Brooklyn Bridge in service forty years. When the Blair railroad bridge over the Mississippi was removed after forty years' service, the structure showed no signs whatever of deterioration. Is there a better monument to the dependability and stability of the riveted joint?

Modern steel shipbuilding history is a story of rivets. Keels, decks, hulls, superstructures, boilers, and even masts are built of riveted steel. America's activity in ship construction during the World War brought most forcefully to the public's attention the dependability of riveting. There are 700,000 rivets in a 7500-ton cargo ship, and American shipyards averaged approximately 280,000 tons gross weight per month during that period.

In automotive construction 90 per cent of the riveting is done cold, a very successful and economical process. The companies who use welding extensively are also the greatest users of rivets. Spot and seam welding have their places in body construction, but have not taken precedence over riveting. Automotive manufacturers the world over entrust the safety of humanity and cargo to a riveted chassis frame.

Railroad equipment, boilers, bridges, buildings, tanks, stacks, gas holders, automobiles, tractors, cranes, concrete mixers, agricultural implements, etc. all reflect the dependability of riveting and its contribution to engineering progress.

There is a field of usefulness for both riveting and welding. Riveting stands firmly upon its record, an accredited success as a fabricating process. It has played a very important part in the development of our most important industries and will only be supplanted by methods more economical, less dependent on skilled labor, and assuring equal safety.

IN THE oral discussion that followed, H. G. Reist[12] said that the General Electric Company had made quite extended use of welded material on generator construction of much larger size than was discussed in the paper and had found it very uniformly satisfactory.

One difficulty that had come up in connection with the use of rolled steel was the design of the machine. Sometimes it was very difficult to utilize rigid straight material such as obtained in rolled plates or beams and have them look satisfactory; however, gradually this difficulty was being overcome.

A. G. McKee[13] asked how in a practical way the chance of defective work could be eliminated in the shops where this kind of work was done for those who did not control the actual operation of manufacturing materials by welding.

H. B. Oatley[14] referred to the author's remarks regarding fusion welding or arc welding being permitted in superheaters and steam piping, whereas they were prohibited in boilers. There was a phase of this which has not been touched on in the paper. It had nothing to do with cost or saving in weight or anything of that sort, but it had to do with the extreme severe service of superheaters in general as regarded high temperature. Furthermore, in the case of most designs of superheaters, it had to do with the internal area of the pipes, which meant steam area between the boiler and prime mover, and it was a vital thing to maintain the steam area as originally intended. It was practically impossible to determine

[12] Designing Engineer, General Electric Co., Schenectady, N. Y. Mem. A.S.M.E.

[13] President, Arthur G. McKee Co., Cleveland, Ohio. Mem. A.S.M.E.

[14] Vice-President, in Charge of Engineering, Superheater Co., New York, N. Y. Mem. A.S.M.E.

what the area was after such welds had been made, in the railway field particularly, and there 50,000 superheaters were in use.

Hundreds of pipes had been found where the steam area had been reduced by at least 50 per cent where the internal portion of the weld had closed the steam area.

V. M. Frost[15] said that reference had been made to welding being prohibited in the A.S.M.E. Boiler Code. It was not prohibited there and no mention had been made in the code as to whether arc welding or gas welding might be used. Welding was permitted provided other forms of construction carried the stress and strain. It was perfectly allowable to weld the joint between the lines of staybolts on the midline which, theoretically, carried no load. As to superheaters, his company had quite a few of them, but none of them were welded. In years gone they had one which was gas welded, but welding was used only for tightness, not for strength.

As to the author's statement that one man was killed every day by the explosion of a riveted boiler, F. R. Low[16] said that statistics for the year 1925, furnished him by S. F. Jeter, Chief Engineer of the Hartford Steam Boiler Insurance Co., the latest year in which there were complete records, showed that there were 169 boiler explosions and 170 other accidents usually classed as explosions, such as ruptures of tubes, heads, etc. As a result of the 169 real explosions, 133 people lost their lives. However, 53 of these were killed in a steamboat boiler explosion due to excessive corrosion, and for which neither welding nor riveting could be held responsible.

G. S. Case[17] asked regarding the small industrial plant which did not use welding in its production. His company had a great many relatively small machines which required repairs, the result being that they had to have expensive pattern storage and it very frequently cost them more to find a pattern and get it out for a repair job than to make a new one. It was probably cheaper for them to go on with the patterns and castings than to use very skilled men on welds and inspection. What, now, was the hope for them in welding?

AUTHOR'S CLOSURE

THE discussion on the paper, as would be expected in a matter of this kind, is widely varying in the conclusion arrived at. Those who have had actual experience with arc welding speak very favorably of its possibilities; those who have had little or no experience with it speak with some heat on its shortcomings. This has always been true of anything which is new.

There has never been any scheme proposed in engineering, politics, religion, or in any other activity of mankind, but what has been ably supported by a certain few and wildly condemned by the uninitiated majority. As is usually true, those who condemn it do it without the knowledge of the facts and undoubtedly could make a much better story in their condemnation were they fully aware of the facts.

Messrs. Belding, Quirke, and Jensen condemn welding rather heatedly, all of them condemning it for certain rather widely separated reasons.

Mr. Belding states it is impossible to make a weld anyway by the fusion process, that it only can be made by hammering or working of the metal in some way. It would seem to the author that the mere statement of this is its own answer unless the word "welding" means in his vocabulary something radically different from what is meant in the vocabulary of other people.

All airplane fuselages have been, from the very first, fusion welded. In talking to airplane manufacturers the author has yet to find one case where failure has occurred, yet in the case of the airplane the weight of the structure must be held to a minimum and therefore the strength of the joint brought to its maximum. All of the airplane manufacturers talked to (and this includes all of the important ones) have stated definitely that it would be absolutely impossible to successfully make a fuselage by any other known method than welding without enormous increase in weight and probably great difficulty because of deterioration of the joint from vibration.

Stills for cracking oil is another case that perhaps demonstrates fairly well the advantages of welding. In this case not only must the still carry terrific pressures but also carry them at very high temperatures. There is still some diversity of opinion among the refining companies as to which is the better, although it is a rather indicative fact that those who are using welded stills continue to buy nothing else. They also are the ones who are using the highest temperatures and the highest pressures.

Any number of examples of this kind can be cited. It is rather hard, therefore, for the author to believe that a true weld is not being made by the fusion process.

Mr. Quirke speaks very feelingly of the metal alongside the welded joint. This statement has been made so frequently that perhaps a discussion of it will be of value.

Any steel acts the same way in the heat of the arc as it does in the heat of the forged fire, or as it does heated by any other known method. No one acquainted with the properties of steel and of heat treatment would expect that steel carrying an appreciable amount of carbon would be the same with varying kinds of heat treatment—in other words, if a bar of steel carrying, say, 30 points of carbon were heated up to molten temperature and quenched, the author doubts if many persons who have had any experience with steel would expect that it would have the same properties of strength, ductility, and appearance that it would have if it had been annealed and rolled during the annealing process. In fact, we have an enormous industry which is built up around the one process of heat treatment of steel. Now any one who has ever seen a weld made in plate knows perfectly well that at the point of welding the metal is molten, but at a very short distance from the point of welding the metal is cold. Because of the heat capacity of this cold metal the metal alongside the weld will be chilled or carried from its molten temperature to a low temperature very quickly, and while it will not be quenched in the same way that we speak of quenching in heat treatment, yet the results will be very similar. With that in mind it is self-evident that what the result is in the metal which has been melted and the metal immediately adjacent to it, is going to be determined to a large extent by the steel itself, or drawing a definite conclusion from the facts, it is self-evident that if the metal has no carbon in it at all that there will be no change in the structure. If it has some carbon in it the result will depend on the amount of carbon that it carries. It would therefore not be surprising to see the metal alongside the weld crystallized under conditions of welding, provided it had a sufficient amount of carbon in it.

The important thing, however, is not what is the structure of this metal nearly as much as what are the comparative properties. There are any number of cases where specifications call for coupons to be cut out of the weld and that these coupons in a pulling machine must have a strength 90 per cent of the strength of the plate itself. Welded joints have no difficulty in meeting this. A rather unusual fact has developed from thousands of tests of this kind in which the metal breaks at 90 per cent or even less than 90 per cent, not in the weld, not in the metal adjacent to the weld, not even in the metal close enough to the weld to have even been affected by it, but in the metal inches away from the weld and inches away from any possible effect from the welding process.

There is only one conclusion that the author has been able to draw from this and that is that the metal itself will vary more than 10 per cent in strength from the expected strength of the plate. This would never have been found by riveting because the joint could not be made strong enough so as to make the metal break outside of the joint. It is frequently found, however, in welding.

Mr. Quirke also states that welding is not satisfactory in locomotive boilers. It is a rather remarkable fact, however, that it is still used to an enormous extent in locomotive boilers and to an increasing extent. The author thinks it is safe to say that there are very few locomotives in operation today which do not have their tubes welded into the flue sheet. As a matter of fact, most locomotives at the present time have their tubes welded in before they ever leave the factory where they are manufactured.

A rather serious misstatement has been made by Mr. Quirke in regard to the Mokelumne River pipe line. In this particular case the author happens to know the facts which, judging from Mr. Quirke's statement, he does not.

---

[15] Asst. to Gen. Supt. of Generation, Public Service, Elec. & Gas Co., Newark, N. J. Mem. A.S.M.E.

[16] Editor, *Power*, New York, N. Y. Past-President A.S.M.E.

[17] Treasurer and Factory Manager, Lamson & Sessions Co., Cleveland, Ohio. Mem. A.S.M.E.

The pipe line is ninety miles long—it carries the water from the Mokelumne River to the bay cities in California, is 63 in. in diameter, and the majority of it is made of $^1/_2$-in. plate. There has been no difficulty whatsoever in connection with the welding of the pipe. This pipe was made by taking two sheets rolling them into half-circles and welding them together automatically with the carbon-arc process, each section 30 ft. long. After they have been welded they are put into a testing machine, put under hydrostatic pressure and the metal in the pipe is brought to a tensile stress in excess of 20,000 lb. per sq. in. While under this stress each foot of weld is hammered with a 19-lb. sledge, each pipe being struck 60 times. If the pipe withstands this test without any leak it is passed. Any one with any experience in connection with riveted pipe is perfectly well aware of the fact that it is absolutely impossible to make a riveted pipe which will withstand any such test.

It is also a fact in this particular case that bids were taken both on riveted and on welded pipe. There was a saving in excess of $3,000,000 by the use of welded pipe—there was a saving in material of 50,000 tons. The weight of the metal in the welded pipe line was 78,000 tons, and the figured weight of the riveted pipe line to give the same factor of safety was 128,000 tons. Not only would the sheets making up the riveted line have to be heavier because of the weakness of the riveted joint, but the diameter of the pipe would of necessity have to be increased by nearly 10 per cent to compensate for the friction of the rivet heads and the butt straps.

Probably what Mr. Quirke means is that there was a good deal of difficulty with the welding of the sections together in the field. It happens that this was done with a process radically different from that employed in the manufacture of the pipe. While the author has no connection whatsoever with the field work, he nevertheless happens to have come in contact with it a good deal in his connection with the manufacture of the pipe itself.

It is true that a good deal of difficulty was found with the welding of the sections together in the field by the gas process. It so happened that there were not sufficient operators who could weld these sections in the proper way, and considerable difficulty was encountered for that reason. There was, however, somewhere in the neighborhood of a mile of pipe welded up by this process, and the fact that this mile is in operation at the present time and has been now for a year and a half without the slightest sign of a leak, is a fairly good indication that the process was not entirely wrong. All of the line would have been electrically welded after the difficulty which occurred on the gas welding had it not been for the fact that the contractor was not equipped with apparatus to electrically weld it but was equipped to rivet it. Since he got nearly 50 per cent more per joint for riveting it, he believed that it was to his interest to continue riveting and save himself the necessary investment in welding equipment.

The author can safely say that the buyers of the pipe line would be very glad if the entire field work were electrically welded because of the fact that it then would be tight.

Mr. Jensen properly mentions the great debt that we owe to the rivet. There is no doubt that it has been a very great help to us in our building progress—many things would have been impossible without it. However, many things now are impossible in the light of riveted construction which are very necessary to the progress of mankind.

Mr. Jensen also points to the use of the rivet in the automobile industry. However, it is a rather remarkable fact in the light of his statement that practically all rear-axle housings are arc welded, and that in many cases the brake hangers are are welded. In many cases the body has much arc welding done on it. It is also true that in most of the cases where arc welding is used it is used not alone because it is cheaper but because it is impossible practically to do the job in any other way except by arc welding. There are any number of cases where arc welding should be used and eventually will be used where rivets are now used, but because of custom and because of lack of training along the line of progress, the old method of riveting is clung to when arc welding would be very much better.

It is not surprising that a process which in its commercial application is but very little over ten years old should not be entirely adopted immediately. About the same time that arc welding came into the field of attention this country fought a war to make the world safe for democracy. We are still somewhat short of our goal: we still want to make the world safe for democracy, but we just have not got around to doing it yet. Perhaps the same thing is true regarding arc welding.

It is interesting to note that the discussers who have had experience with this process, such as Messrs. Owen, Farmer, and Reist, can see nothing but a very brilliant future for it; and it is the author's belief that their conclusions have been arrived at in the light of experience rather than in the light of prejudice. It is his belief that any one who will get the facts will come to the same conclusion that they do.

We should not lose sight of the fact that the most important application for arc welding is in the replacement of castings, forgings, and riveted structures with arc-welded steel. This process will eventually eliminate most castings and practically all riveted construction. It will therefore be one of the greatest booms to the manufacturer that he has ever received, and the manufacturer who first adopts the process will thereby obtain a tremendous advantage over his competitor.

Qualities of Fireclay Refractories

THE study of the fundamental qualities of representative fireclay refractories and individual clays has been referred to and described in *Technical News Bulletin* No. 117 (January, 1927) and No. 121 (May, 1927). The effect of reheating at high temperatures on the thermal dilatation has now been observed. The importance of thermal dilatation as a factor controlling resistance to thermal spalling has been discussed at length in recent literature and the significance of differential thermal dilatation and fiber elongation was briefly referred to in *Technical News Bulletin* No. 121. Factors of possible significance are not only the differences in thermal dilatation of the various constituents of the refractory structure, but also the difference in thermal dilatation between adjacent portions of a structure.

In actual service nine-inch brick are usually laid in header courses, that is, only the $2^1/_2 \times 4^1/_2$-in. end is exposed directly to the heat. Since fireclay refractories are fairly good heat insulators, the maximum temperature 2 in. from the "hot face" may never exceed 1200 deg. cent. (2200 deg. fahr.), even though the hot face is heated for prolonged periods as high as 1450 deg. cent. (2642 deg. fahr.). Since clay refractories are initially fired at temperatures from 1250 to 1275 deg. cent., it is unlikely that the structure 2 in. from the hot face would be greatly affected in service. However, the data obtained show that the material at and immediately adjacent to the hot face may be changed very materially as regards thermal dilatation.

Average values for seventeen representative brands of fireclay show that reheating at 1400 deg. cent. (2552 deg. fahr.) for five hours reduced the per cent linear thermal expansion and contraction of the brick (calculations based on values obtained on brick as received) by 0.04 per cent, and that the per cent linear expansion from room temperature to 900 deg. cent. has been changed by 0.1 per cent. Furthermore, reheating at 1500 deg. cent. for five hours changed the per cent linear expansion from room temperature to 200 deg. cent., an average of 0.07 per cent, and from room temperature to 900 deg. cent. it was changed 0.15 per cent. Certain brick of the siliceous type showed changes greatly exceeding these average values. The maximum changes observed were as follows: (*A*) (after reheating at 1400 deg. cent. for five hours) room temperature to 200 deg. cent., 0.09 per cent change in linear thermal expansion; room temperature to 900 deg. cent., 0.17 per cent; (*B*) (after reheating at 1500 deg. cent. for five hours) room temperature 200 deg. cent., 0.16 per cent; room temperature to 900 deg. cent., 0.30 per cent.—*Journal of the Franklin Institute*, October, 1927, pp. 533–534.

The Effect of Atmospheric Smoke Pollution

A Summary of Opinions from Current Literature

By A. S. LANGSDORF,[1] ST. LOUIS, MO.

THE late humorist, Josh Billings, having advertised that he would give a lecture about milk, opened his discourse with the remark that the best thing he knew on milk was cream. His exposition had the merit of getting at once to the point, and if his example may be followed in enlarging upon such a subject as that of this paper, it may be stated without further ado that atmospheric smoke constitutes not only a nuisance but a source of danger to numerous living organisms, including human beings, and a serious menace to the permanence of a great variety of inert materials. It is the considered opinion of qualified experts in many branches of scientific work, such as medicine, botany, physics, chemistry, and engineering, that the evil effects are sufficiently grave to warrant the most active efforts for the elimination of their cause. But the fact remains that in the large cities the general public can be roused to remedial action only with the greatest difficulty, and that no effective means have yet been found to prevent relapse to customary lethargy and indifference even after a spurt of activity has resulted in easily noticeable improvement. The difficulty in all attempts at smoke abatement is that the injurious effects of the nuisance are for the most part so slow in their action as to cause little uneasiness to the average person; in general, the situation is not unlike that prevailing in other instances requiring reform, where bad conditions must often be allowed to become insufferably worse before they can be made better.

The abundant literature concerning the effects of atmospheric smoke may be grouped under three main heads: (*a*), medical, dealing with the effects of smoky air upon human health; (*b*), botanical, concerned with injuries to vegetation; and (*c*), physical, including such chemical aspects of the problem as are involved in the deterioration of inert materials. To these classifications might be added a fourth, namely, the economic, but this is so closely related to the others that it can hardly be considered separately. At any rate, it is clear from this classification that no one individual is qualified to speak with authority on all phases of the subject, and that at least with respect to the first two indicated above, an engineer cannot be expected to do more than review the situation from the point of view of a layman.

The bulletins of the smoke survey in Pittsburgh, conducted by the Mellon Institute of Industrial Research, provide a very convenient and complete summary of the subject up to the year 1914; and the Chicago Report on Smoke Abatement, published in 1915, is likewise valuable as a comprehensive statement of conditions and opinions up to that time. A bibliography of subsequent publications has not been compiled, so far as the author is aware, but an examination of the more important books and articles leaves no doubt that most of the earlier conclusions as to the injurious effects of smoke have been amply confirmed. But whereas in much of the earlier literature smoke was simply smoke, and black smoke in particular, the current tendency is to get away from the habit of thinking of it as a single entity, and to resolve it and its effects in terms of its constituents. This distinction is most important, for it raises the grave question whether smoke abatement, as that term is popularly envisaged, will in the long run relieve us of the worst of the evils we wish to eliminate.

Physical and Chemical Deterioration Caused by Smoke

Consider, for example, the obvious physical and chemical deterioration caused by smoke. It is easily possible to evaluate the extra cost to the people of a large city caused by cleaning and washing clothing, curtains, carpets, draperies, and paintings, nearly all of this "black-smoke tax" being due to the sooty and tarry airborne particles; in shops and stores fabrics on the shelves become soiled and shopworn; walls of buildings, both inside and outside, require increased labor and expense for cleaning and painting. So also may be computed the extra cost of artificial lighting due to the cutting off of natural daylight by the smoke pall. Such calculations, complete to the smallest details, have been made many times for numerous communities, and the results are commonly promulgated in terms of millions of dollars of unnecessary expense, and tons of sooty deposit per square mile per annum. In St. Louis, for instance, the annual cost of black smoke has been estimated at about $15,000,000, and the annual deposit of solid matter at 900 tons per square mile. These figures are impressive, but somehow they leave the "man on the street" singularly indifferent; perhaps he figures that the per capita cost of about $20 is only the equivalent of one extra tire for his automobile, and that the vast accumulation of dust and dirt, when reduced to more familiar units, is a trifle over one ounce per square foot per annum. Whether he thinks about the matter in this way or perhaps not at all, there is little doubt that the cost of cleaning is much more obvious to his wife. The following excerpt from an English book by Cohn and Ruston[2] would find plenty of corroborative testimony from American women:

> A lady who formerly resided in Leeds and removed to a similar establishment in the country (i.e., the same size of house and the same servants) informed me that the quantity of soap used in cleaning a room is less than half of that used in Leeds, the labor of cleaning less than a quarter. Windows which require cleaning once a week in Leeds, only require it once a fortnight and sometimes once a month in the present house. White curtains which were black in three weeks in Leeds, now lasted eighteen months.

The significant fact that the effect of smoke is not confined to the mere blackening of materials is indicated by the following paragraph quoted from another recent English book:[3]

> The corrosive effect of a smoke-laden atmosphere upon metals is too well known to require emphasis here. The sulphur contained in coal is sent into the air in the form of sulphurous or sulphuric acid, and is probably almost immediately all converted to the sulphuric state by oxidation.

This emphasis upon the effect of one of the ingredients of smoke is much more prominent in recent studies than was the case a decade or so ago. In both of the books referred to, as well as in numerous other references, it is pointed out that the sulphuric acid in the air and rain reacts chemically with limestone (calcium carbonate) to form the sulphate, which, being less dense than the original carbonate, produces an increase of volume and a consequent spalling of the stone because of the bursting action. With magnesium limestone the effect is even more injurious, for the sulphate of magnesium is soluble in water, and rain therefore produces an active disintegration. Much detailed information concerning the damage to government buildings in various English cities can be found in a paper[4] by Sir Frank Baines, Director of H. M. Office of Works, published in the Report of the Smoke Abatement Conference held at Manchester in November, 1924. It is needless to repeat the figures here, though the aggregate of $600,000 per annum is large enough to arrest attention. It should be noted in passing that the damage is not confined to stonework, since paint is ruined, and metals, especially unprotected iron and steel, are strongly attacked.

Damage to Vegetation

The physical effects, then, are not only definitely probable, but can be evaluated to a fair degree of accuracy in terms of money. Equally definite, though the monetary equivalent is more difficult to estimate, is the damage to vegetation whenever smoke-polluted air is present. But whereas the impression once prevailed very generally that the injury was due mainly to the clogging of the

---

[1] Director, Industrial Engineering and Research, Washington University, St. Louis, Mo.

Presented at the First National Meeting of the A.S.M.E. Fuels Division, St. Louis, Mo., October 10 to 13, 1927.

[2] Smoke, A Study of Town Air, Cohn and Ruston, Edward Arnold and Co., 1925.

[3] The Smoke Problem of Great Cities, by Shaw and Owens, Constable and Co., Ltd., 1925.

[4] The Effect of Atmospheric Impurities on Buildings.

leaf pores (the stomata) by the sooty and tarry deposit, botanists now consider that the sulphuric acid is the chief cause of the damage. There is such an abundance of published material on this subject, much of it the result of painstaking scientific research, under both laboratory and field conditions, that the preparation of a complete bibliography would in itself be a large undertaking. A particularly thoroughgoing research is embodied in a book entitled Beschädigung der Vegetation durch Rauchgasen und Fabriksexhalationen (Damage to Vegetation by Smoke Gases and Factory Fumes), by Dr. Julius Stoklasa of Prague. Here, as in other works on the subject, the clogging of the stomata is pointed out as a source of injury, especially in the case of evergreen species whose leaves are subject to this effect all the year round. But deciduous species are without foliage in the winter when the smoke nuisance is most pronounced, hence the indubitable fact that many choice varieties die off in smoky cities is an indication that another cause is the active factor. The researches that have been made include determinations of the effect of varying amounts of sulphuric and sulphurous acids in the air, in the soil, and in the water (including rain) used for irrigating the plants; the studies include the effect upon trees, flowering plants and shrubs, and the principal cereals and grasses. In all of them the result is the same—the effect of these acids is deadly. In St. Louis it is known that bluegrass lawns cannot be maintained because of the strongly acid soil; and in some parts of the city which were far removed from the smoke belt twenty-five years ago, and which then had large numbers of stately laurel oaks, trees are now conspicuous by their absence. The enormous damage to trees and flowers in the public parks and at the Missouri Botanical Garden is well known, the effect being so pronounced that the Garden authorities are now developing a new tract forty miles beyond the city limits.

Seriousness of Effect of Sulphuric Acid

An idea of the seriousness of the effect of sulphuric acid may be obtained from the consideration that ordinary coal may contain from 2 to 3 per cent of sulphur, although certain Illinois coals run as high as 4.75 per cent. If we assume an average of 3 per cent for the 5 million tons of raw coal burned annually in the city of St. Louis, it follows that there are 150,000 tons of sulphur ready for conversion to sulphuric acid. Since one unit of weight of sulphur corresponds to slightly more than three units of weight of sulphuric acid, the total acid equivalent is about 450,000 tons per annum. Only a part of this, however, finds its way into the chimney gas, the rest remaining in the ash. From tests made at Altoona, Pa.,[5] it was found that the percentage of sulphur in the stack gas of locomotives ranges from a minimum of 1.2 per cent to a maximum of 92.63 per cent of the total sulphur fired, the average of 53 tests being nearly 33 per cent. Using this average figure as applicable to ordinary firing, the annual precipitation of sulphuric acid due to coal consumed in St. Louis alone (exclusive of the additional 3 million tons burned in the surrounding municipalities) is no less than 150,000 tons per annum. This enormous quantity is of course not all deposited on the sixty-four square miles of city area, much of it being widely distributed by the wind; but on cloudy, windless days and nights its presence in the form of pungent sulphur dioxide is very marked; and wherever it falls upon the soil its action is cumulative.

Harmful Effects of Smoke on Health

It may therefore be stated as an established fact that smoke pollution produces definitely known damage to physical structures and to vegetable organisms. With regard to the effect upon human health the case is not so clear, at least so far as convincing scientific proof is concerned. All the indications point to harmful effects, and there is no lack of medical opinion that smoke is responsible for many ills, but with all due respect to the authors of the medical literature in which smoke is held responsible for much morbidity, the unprejudiced reader is bound to admit that conclusive demonstration is lacking. The author has made a search of medical literature beginning where the bibliography of the Mellon Institute left off (in 1913), by looking up most of the references to be found in the Index Medicus and the Quarterly Cumulative Index of Medicine. Much reliance seems to be placed on statistical studies, of which those of Dr. Louis Ascher of Königsberg are especially noteworthy. In general, such studies seek a correlation between the prevalence of smoke and the mortality due to diseases of the respiratory tract, especially the non-tubercular diseases, and pneumonia in particular. That such a correlation exists is unquestionable, but to what extent it may be accepted as conclusive evidence of the harmful effects of smoke is quite another matter. In the first place, it is difficult to obtain a satisfactory measure of the amount of smoke when the area under consideration is considerable. Accurate apparatus like the Owens automatic air filter, if distributed in sufficient numbers, would give reliable measurements, but unfortunately their use is not general. Resort must be had to the rather crude smoke records of the U. S. Weather Bureau, which are based on the visibility of fixed landmarks from the office window; thus, if the arbitrarily selected mark is visible at the time fixed for the observation, the day is "clear;" if it is not visible, "dense smoke" or dense fog is recorded, according to circumstances. The personal equation of the observer is thus a considerable factor. As an example of such studies, a chart for the period 1921–26 was prepared by plotting the number of deaths due to lobar pneumonia, taken from the official reports of the Division of Health, St. Louis Department of Public Welfare, and the number of smoky days recorded by the local office of the U. S. Weather Bureau. The correlation was certainly striking; but since pneumonia is predominantly a winter disease, it is after all not so strange that the peaks in the pneumonia curve showed a periodicity in step with that of the smoke curve, since in the nature of things smoke will be most prevalent in the winter season when coal is being burned at the greatest rate. Since the records of the Weather Bureau included data concerning dense fog, temperature, and humidity, curves showing their variations were also added to the chart. They showed, as would be expected, the same periodicity as the others, the cause being seasonal. There seems to be no justification whatever for selecting the prevalence of smoke as an index of the pneumonia death rate, at least so far as this particular study is concerned; it may be, and probably is, a factor, but to no greater extent than are the others. Physicians will probably agree with the statement that many diseases are the resultant of so many contributing causes that there is an element of quackery in emphasizing any one of them to an undue extent. Consider the smoke record of the city of Boston, as found in the official reports of the Weather Bureau in that city. In the years 1920–26, inclusive, dense smoke was recorded once, in 1923; in these same seven years, taken in order, the number of days with light smoke was 0, 3, 4, 8, 2, 2, and 4. And yet, in spite of this freedom from heavy smoke, Boston has a relatively high death rate due to pneumonia. According to figures compiled by Wm. C. White and C. H. Marcy,[6] the death rate from pneumonia was third in a list of fifteen large cities, being exceeded only in Chicago and Pittsburgh, the figures covering the period 1907 to 1910, inclusive. That the medical profession is itself not unanimous in attributing all of the blame to smoky air, the following quotation[7] will show:

> I would expect Boston to have a greater mortality from pneumonia than Pittsburgh, on the sole basis of fact that Boston has relatively more people in the pneumonia ages. I would expect Chicago to have a higher pneumonia mortality than Pittsburgh, because there is a pneumonia obsession in the minds of the medical profession of Chicago.
>
> .....I do not think that the pneumonia figures admit of sound reasoning as to magnitude, unless, in the first place, distinctions are made as to the age distribution of the populations which are to be compared; and, in the second place, unless the pneumonia mortality is divided sharply into two groups, those under and those above the age of three years, and the comparison made with reference to these distinctions.

Smoke and Pneumonia

The author hesitates to express personal opinions on such an involved medical subject, but it appears to be plain common sense that pneumonia, being a germ disease, can develop only when the pneumococcus bacillus finds conditions suitable for its propagation.

[5] See Table CDLXXXIX, p. 1133, Smoke Abatement and Electrification in Chicago.

[6] A Study of the Influence of Varying Densities of City Smoke on the Mortality from Pneumonia and Turberculosis, Trans. Fifteenth Internatl. Congress on Hygiene and Demography, 1912; also Bulletin No. 9, p. 155, Smoke Investigation of the Mellon Institute.

[7] Discussion by Dr. John S. Fullerton, p. 165, Bulletin No. 9, Smoke Investigation of the Mellon Institute.

In general, these conditions imply a lowering of the bodily resistance, which may be due to one or more of a great variety of causes; such, for instance, as exposure to a cold and damp atmosphere; weakness due to other diseases, or to insufficient or improper nourishment; and unhygienic manner of living, whether due to bad housing conditions or to faulty personal habits. The fact that pneumonia and other diseases of the respiratory tract follow in the wake of cold, foggy weather, especially when smoke is present, does not necessarily prove that the smoke is the chief factor; although it may be, and very likely is, the element which may be called the last straw in upsetting the equilibrium. The interesting and important results of the studies under way at the Bureau of Mines in Pittsburgh show very vividly the pronounced effect of extremes of temperature and humidity upon human health, even when smoke is not present.

On the other hand, it is not possible to dismiss lightly such testimony[8] as that of Ex-Bailee W. B. Smith, of Glasgow, who relates the consequences of a series of dense smoke fogs in that city in 1909, in comparison with contemporaneous conditions in seven other neighboring towns. These towns were Edinburgh, Dundee, Aberdeen, Paisley, Leith, Greenock, and Perth, with an aggregate population of 993,550 as compared with 872,021 in Glasgow. All of them save one had the same conditions, being planned and built alike, with the same proportion of crowding and slums, with similar sanitation, like methods of heating and cooking, and with the general habits of the population much the same in all of them. During the five weeks ending October 30, 1909, the average death rate in Glasgow from all causes was 13.4 per thousand, while that of the other seven towns was 12.2 per thousand. On October 30–31 there was a heavy fog, followed in Glasgow by a sharp rise in the death rate, which in the week ending November 6 was 18.2 per thousand, as compared with 12.7 in the remaining seven towns. Again, from November 15 to 19 there was an exceptionally heavy fog, and another from December 6 to 8, with death rates as follows:

Week ending	Glasgow	Other 7 towns
November 20	24.9	15.3
November 27	32.7	16.7
December 4	27.3	17.8
December 11	31.7	16.7

The temperature in Glasgow was slightly higher than in the other towns, all other conditions having been similar except that in Glasgow the air was much smokier. This is strong evidence, but it is nevertheless of a circumstantial character. It is reminiscent of the time when malaria was universally attributed to miasmatic exhalations from swampy land and to the evil qualities of night air. Every one knows what a long step was taken when it was finally found that swamps and darkness are nothing more than the stage settings for a particular germ carried by a particular mosquito.

Conflicting Views on Effect of Smoke on Health

In the light of the knowledge that has been won by botanists in studying the effect of the separate constituents of smoke, it no longer seems sufficient for the medical profession to be content with broadsides directed at smoke in the abstract. While physicians are generally agreed that smoke is harmful to health, there is a welter of conflicting views, of which the following is an indication. Thus, Dr. Evans says:[9] "Smoke carbon is probably as little harmful as any solid which can be taken into the human body. It is quite inert chemically. Physically it irritates but little. The harm that it does is that it transports bacteria and secures entrance for them where alone they would be repulsed." The last sentence is flatly contradicted by W. L. Holman,[10] who found that soot has a definite bactericidal action on bacteria, and that soot does not form a favorable nidus for the collection of bacteria.

There is nothing new in the idea that the sulphur dioxide in smoke is injurious to health, all authorities being agreed as to this point. It has been singled out by some writers as responsible for asthma, by others as the cause of sneezing, coughing, and lachrymation, and again as the cause of bronchial irritation and catarrh. But there is extremely little evidence of careful investigations of the quantitative relations between public health (or rather disease) and the harmful constituents of the air. In nearly all cases the conclusions contain the qualifying phrase "it is probable," or its equivalent, when a forthright statement of fact is in order.

It seems quite logical to believe that diseases of the nose and throat will flourish in a smoky community, and that the distribution of nose-and-throat specialists might serve as an index of the prevalence of smoke. But actual facts show that this criterion is not reliable, cities like Los Angeles and Washington, D. C., having a disproportionately large number of such practitioners. Nevertheless there is a strong belief that sinus trouble is most general in smoky cities, and it is believed that the sulphuric acid is the irritant which causes inflammation of the nasal passages and consequent closure of the drainage from the sinus cavities. Here again we find plenty of surmise, but little in the way of incontrovertible proof.

Much attention has lately been given to the effect of smoke in cutting off the ultra-violet radiation from the sun. It is known that ultra-violet light of certain wave lengths has a marked therapeutic value in the treatment of some diseases, such as rickets, and the absorption of this beneficial radiation by the smoke pall is commonly used as an argument for smoke abatement. The author is just as much convinced of the necessity of eliminating smoke as any one could well be, but it must be confessed that he looks upon this use of the ultra-violet argument as a passing fad. In the first place, rickets is a disease due to malnutrition, and while ultra-violet light is very active in promoting the assimilation of calcium into the bones, the fact remains that the patient must be stripped of all clothing to make the treatment effective. It is obvious that the general population is not yet ready to go about in the altogether; and even if that were done, the glass in our windows, being impervious to the curative rays, would nullify our efforts. If ultra-violet rays are as essential as some would have us believe, the people of the tropics should be the most healthy in the world, and the Eskimo tribes should have long since perished. Further, it appears that the active wave lengths are those from 3020 Ångstrom units down to below 2900 units.[11] But in Chicago, at 10:30 a.m. on February 19, 1927, the day being clear with a northeast wind, the minimum wave length in the sunlight was 3030 units; at 3 p.m. on the same day the minimum was 3090 units, all conditions having been the same except that the afternoon sunlight came through the smoke pall from the stockyards district.[12] These figures show that some of the ultra-violet radiation was absorbed by the smoke, but the effective rays were not present to begin with. The weakness of the ultra-violet rays in the winter is due to astronomical causes over which we have no control.

Conclusion

The conclusion seems inevitable that if we wish to obtain really conclusive evidence concerning the harmful effects of smoke upon health, there must be an effort to obtain analyses of the air from numerous stations at frequent and regular intervals over an extended period, just as dust counts are now made at scattered points, and the data so accumulated must be studied in connection with health statistics of a much more detailed nature than are now available. Added to this there should be experimental studies of all of the factors involved, under controlled conditions. Such an investigation calls for a program much more extensive than any yet attempted, and it must have the coöperation of the medical profession as a whole.

In the meantime, all possible steps must be taken to get rid of the smoke plague. Engineering and common-sense methods in the myriad private homes may do much to eliminate the visible evidences of the nuisance. Perhaps the next step will be to eliminate the invisible ones as well.

[8] Should We Longer Tolerate the Pollution of the Air? *British Medical Journal*, August, 1922.

[9] Smoke Abatement and Electrification in Chicago, p. 66.

[10] Smoke Investigation Bulletin No. 9 of the Mellon Institute, p. 120.

[11] The Antirachitic Activity of Monochromatic and Regional Ultra-violet Radiations, by Hess and Weinstock, Proc. Soc. Exper. Biol. & Med., vol. 24, p. 759, May, 1927.

[12] Ultra-violet Radiations from Sunlight and Incandescent Lamps, by H. N. Bundesen, H. B. Lemon and E. N. Coade, *Jl. Am. Med. Assn.*, July 16, 1927, p. 187.

Organizing a Smoke-Abatement Campaign

Technical Division of a City's Engineers the First Essential in a Smoke-Abatement Campaign—Major Activities of Technical Division—Research-Publicity Work—Smoke Surveys—Educational Work—Conduct of Campaign—Appalling Monetary Loss Caused by Smoke

By ERLE ORMSBY,[1] ST. LOUIS, MO.

A SMOKE-ABATEMENT CAMPAIGN in a large city will be successful just in proportion as team work and coöperation may be secured between all classes, businesses, organizations, individuals, etc. It is an engineering program and it is therefore of vital importance that the engineers of the city become interested and donate a large amount of valuable time to the work. Furnace, boiler, and equipment manufacturers, fuel dealers, and producers must become interested and must work together for the common good. The power-plant owners, factory owners, and the clay-products plants must become interested in working out their problems in relation to smoke abatement so that the investment which may be required will be a profitable one in fuel conservation and more satisfactory operation. The owners of apartments, hotels, and large heating plants, and the real-estate men who operate them must become interested in keeping their equipment in order and training their janitors to reduce smoke and save fuel. Last, but not least, the operators of domestic furnaces must take an active and lively interest in the subject from the standpoint of fuel saving, cleanliness, better house heating, and civic pride.

Coöperation Essential in Smoke Abatement

Coöperation is the magic watchword in smoke abatement, and the movement will be successful just in the proportion that universal coöperation is secured. It is manifestly impossible to secure 100 per cent coöperation as there are always some people who are ready to say "It can't be done," and others who would rather propose some ideal solution which may become effective 10 or 20 years from now than to coöperate in a general movement which will give us results immediately. We have found in St. Louis, however, that a large proportion, probably over 90 per cent, of the people are interested in smoke abatement, and willing to coöperate in a city-wide movement. Our demonstrators have found that all but two or three families in a block will readily learn how to fire their furnaces in an efficient and smokeless manner, and they are usually delighted with the results. The ideal plan is for the Smoke Abatement League to use their educational campaign and demonstration methods for the 90 per cent who will coöperate and turn over the 10 per cent who will not coöperate to the City Smoke Department, who will then talk to these people in the only language which they can understand, the language of force.

It is not always possible to secure this coöperation with the city. It sometimes happens that the city officials are more interested in political preferment than they are in smoke abatement, and will not coöperate with the Citizens' League for fear they will have to divide the credit for results secured.

Smoke abatement is essentially an engineering program; a practical investigation into the complete and smokeless combustion of fuel, not only in the great central stations and power houses, but in industrial plants, clay-products plants, laundries, railroad locomotives, hotels, warehouses, office buildings, apartments, and household heating plants.

Technical Division of Engineers the First Essential in a Smoke-Abatement Program

The first essential of a smoke-abatement program is to get the engineers of the city interested and organized into a technical division with sub-committees for each fuel-consuming class, led by the ablest men in each division. To the engineer there are no smoky fuels. It is merely a matter of the proper mixture of the oxygen in the air with the gases from the fuel at a reasonably high temperature. The volatile gas, which constitutes from 25 to 40 per cent of the smoky or high-volatile fuels, is rich in heat value, and as a matter of economy and fuel conservation should be burned efficiently to produce heat instead of smoke. That it can be done has been proved, not only by engineers, but by average citizens—women as well as men—in thousands of cases. The users of domestic furnaces *can* and *must* learn to burn their fuel smokelessly and in so doing they will encourage manufacturers to build and the people to buy more foolproof and more smokeless equipment.

Modern civilization is a high-powered civilization. It is also a mechanical civilization, made possible by mechanical and electrical inventions and proficiency, and resulting in the massing of one-half of the population in the more densely populated urban centers where millions of tons of fuel are consumed in a comparatively small area. The people of this country are accustomed to mechanical and electrical contrivances—the automobile, the radio, etc. They learn the principles of combustion as explained by a competent engineer in a surprisingly short time and get most excellent results from their furnaces after a short demonstration.

Activities of the Technical Division

The technical division has five distinct lines of activity: First, to devise better methods of burning our fuels in our present equipment. People do not readily change from their present methods in any department of life, and the householder must first become interested in studying his own furnace in its relation to cleanliness, smoke abatement, and economy of fuel. When once he learns that there are ways of handling his furnace which will give him more satisfactory results, he becomes interested in the whole problem and an active advocate of smoke abatement. Second, to train instructors in these methods. It is necessary that there should be a force of trained men going from house to house, and giving instructions in the handling of fuels and furnaces. The city should be divided into districts, each district in charge of a supervisor with a sufficient number of assistants so that the chimneys may be watched and the person responsible for the smoking chimney given proper instructions. If the party cannot be interested, the city smoke department should handle the case. Third, to design better equipment for the efficient and smokeless combustion of fuels which are inclined to produce smoke. The furnace and boiler manufacturers, like all other industries, produce what the people demand. The Smoke Abatement League must build up a demand for better and more smokeless heating equipment and must help the manufacturer to supply this demand with a not too expensive smokeless boiler or furnace. Fourth, to devise improvements which may be applied to present furnaces to assist in procuring smokeless combustion. This is very important as it will be many years before all the heating plants in the city can be renewed with equipment built especially for smokeless combustion. The ready means of converting existing furnaces will be a large factor in smoke abatement. Fifth, to organize a power-plant subdivision to induce the various factories, industries, power plants, large heating plants, etc., to install smokeless equipment and see that it is properly operated by competent men. It is of great value in these cases to have the well-designed smokeless plants written up for publication in the newspapers, together with the name of the owner, the engineer responsible for the work, etc. This will have the effect of making smoke abatement a matter of first consideration in the minds of engineers who design plants, which has not been true in the past, and will also enable the League to point offenders and people who contemplate building new plants to a list of economical and profitable furnace installations, where they may go and see for themselves what results are being obtained and make their own

[1] President and General Manager, Donk Bros. Coal and Coke Co.; President, Citizens Smoke Abatement League of St. Louis.

Presented at the First National Meeting of the A.S.M.E. Fuels Division, St. Louis, Mo., October 10 to 13, 1927.

choice, both as to the type of equipment they desire to buy and the engineer whom they desire to employ.

RESEARCH WORK A MAJOR ACTIVITY OF THE TECHNICAL DIVISION

Research work should be one of the major activities of the technical division. In the cities where high-volatile bituminous coal is the principal fuel, there are several technical questions remaining unsolved. In certain classes of equipment, such as small hot-water heaters, portable boilers such as are used in steam shovels and road equipment, vertical boilers and other types of equipment with very small combustion space, it is extremely difficult to burn high-volatile fuels without making smoke. There are also certain classes of service, such as heating in churches and also high-pressure boilers which are used for peak loads, where smoke troubles are often encountered. The technical division must determine where the line can be drawn between the use of the coking method of firing on straight grates and a furnace requiring additional combustion facilities, such as drop arches. Much additional information is needed on the operation of domestic heating plants. The technical department should conduct research along such lines in an effort to solve these problems.

PUBLICITY WORK

One of the most important phases of a smoke campaign is the publicity work. In most of our larger cities smoke abatement is very largely a problem in mass education. Much of this educational work must be carried through by means of publicity, especially free newspaper publicity. A publicity division with an experienced man as chairman is recommended. In St. Louis we have found the best plan is to employ an experienced publicity man on a part-time basis. Almost every day during the smoky season of the year prepared articles are sent to each newspaper. It will usually be found that the newspapers are quite public spirited and will be glad to coöperate in a campaign of this nature.

There should be no "soft pedaling" of the damage caused by smoke. The people must be thoroughly aroused to the tremendous losses from smoke, and this feature should be stressed from all angles. Not only the property damage and the losses from excessive laundry, cleaning bills, etc., but the tremendous waste of fuel should be emphasized. It will also be found that the deleterious effects of smoke on health appeal to the public, especially its effects on the health of children. Some leading citizens will doubtless object to a program of this nature as they fear it will have a bad effect on business and tend to drive industries away from the city. Our experience has been that the people must be thoroughly aroused in order to get them in the right frame of mind for coöperation in the campaign. Along with this the public must be "sold" on the idea that smoke represents a waste and is preventable. Also people must be shown that smoke can be reduced. Almost every one is in favor of smoke abatement, but there are usually many skeptics who say that "it can't be done." The issue should be kept before the public continuously, not only in the newspapers, but with all other forms of publicity which finances will permit.

SMOKE SURVEYS—WHAT THEY SHOULD INCLUDE

One of the first things to do in launching a comprehensive smoke campaign is to make a smoke survey of the territory. The bulk of the first year's activities may well be devoted to this work. When an engineer attacks any sort of a job, the first thing he wants to know is what the job really is. The survey accomplishes a twofold purpose. It establishes standard conditions which can be compared with conditions in other cities and by which the progress of the work in future years can be measured. After a campaign has been in progress for some time there will always be those who say, "The smoke is as bad as it ever was, you haven't done anything." With the actual survey figures in hand, concrete results can be shown.

The survey should include a study of meteorological conditions, which can easily be done in coöperation with the Weather Bureau. This will establish the average velocity and direction of the wind, fogs, humidity, and other phenomena observed by the Weather Bureau. There should also be a fuel survey of the territory showing the kinds and amounts of fuel used by each class. Comprehensive Ringelmann chart observations should be made of the entire territory during the heating season. These observations should be made on all classes of plants in the district; should be made at different times of the day and at different periods of the year. From the fuel-survey figures and the average smoke densities the percentages of the total smoke made by the different classes of fuel users can be established. This eliminates the guess work and offsets the natural tendency to "pass the buck" and blame the smoke on the other fellow. Another part of the survey is a soot-fall study, determining by customary methods the amount of soot fall in tons per square mile per annum. This gives a very good basis for comparison with other cities.

The results of the year's survey will show what classes of plants are responsible for the smoke. This will then give a basis for detailed operation of the campaign. Efforts can be concentrated on those classes of plants which are making most of the smoke. The survey should be continued every year. Systematic chart readings should be made during the entire heating season, and soot-fall study carried on. This gives a measure of progress of the work and will show at any time just what results have been accomplished.

EDUCATIONAL WORK

In St. Louis we have found the educational division to be one of the most important parts of the organization. This division is organized into a number of committees covering different phases of the work. In a comprehensive smoke-abatement campaign in a large city there are many ramifications of the educational work. The greater the number of people reached through the educational work, the greater will be the degree of success of the entire campaign.

One of the important divisions of the educational work is a speakers' bureau. In St. Louis some 75 public-spirited men and women volunteered their services for a speaking campaign. An active campaign should be carried on to have speakers appear before every organization whom it is possible to interest. Most organizations are interested in hearing about smoke problems and the progress of the campaign.

We have felt in St. Louis that this work should include education of the younger generation. A very active school committee was organized and they prepared a course on heating and furnace firing, which has been adopted by the St. Louis Board of Education and is being considered by public schools in the suburbs and by parochial and private schools. Another phase of the work is preparation and distribution of firing charts, giving instructions written in simple language and properly illustrated, showing approved methods of firing high-volatile bituminous coal. It is also an excellent idea to publish bulletins from time to time on the progress of the work and also educational bulletins covering all the different phases of the smoke problem. These should be sent out to a rather large mailing list of representative citizens who have shown particular interest in the campaign.

In any city where a great deal of high-volatile bituminous coal is used for heating, it is an excellent idea to have a furnace-firing school where practical instructions can be given to householders and janitors. The St. Louis Furnace Firing School was established last year through the coöperation of the coal, coke, furnace, and boiler industries. This school occupies a building about 25 by 75 ft. where six warm-air furnaces and three steam boilers are in operation. The different makes of furnaces and boilers on exhibit cover the most common types in use in St. Louis. Free instruction is given to all interested. The practical demonstration on a furnace or boiler in operation is given by an experienced demonstrator. At one end of the building is a lecture room where lectures are given to special classes of janitors and any interested organizations. The local furnace manufacturers and distributers furnished the furnaces and equipment for demonstration, and their engineers assisted in training the instructors.

There should be a smoke ordinance providing some penalty for violations. There are always some people who will not coöperate in an educational campaign and to whom the strong arm of the law is the only appeal. This, however, should be the last resort after the educational campaign has been well carried out. There are always some who feel that the way to eliminate smoke is to pass and enforce a drastic ordinance. Experience has shown that this does not accomplish the desired results.

When a business man receives notice that he is to be sued for

violation of the smoke ordinance, he immediately turns the matter over to his attorney. The smoke problem in that particular plant is then taken out of the hands of the engineers and given into the hands of the lawyers. It usually becomes involved in a mass of legal technicalities, which generally result in interminable continuances in court. During this time the plant practically has a license to continue the violations indefinitely. At the same time the man will reach out for political protection. The lowest class of political activity is brought into the case, and often results in the case being dismissed on payment of costs. Nothing has really been accomplished except to antagonize the steam user and set him against smoke abatement and all further efforts to improve his condition. A policy of prosecution weakens the case and slows up the process of cleaning up a city.

On the other hand, a policy of education entirely separate from court procedure or political activities makes much more rapid progress. Most fuel users welcome educational efforts as it means fuel saving and better satisfaction in the operation of their plant.

Other well-meaning people interested in smoke abatement from a civic standpoint are prone to advocate a program of universal use of smokeless fuels. The policy in this respect must be determined by the fuel conditions in the city under consideration. Where smokeless fuels are available in large quantities, and the prices considered reasonable by the buying public, such a policy might be advisable. In St. Louis, where we have the coöperation of all the different fuel interests, we have found it necessary to adopt a policy of recommending no change in fuels. St. Louis is located in close proximity to the vast bituminous coal fields of Illinois, and much of the prosperity of our city is built on the availability of good cheap fuel. The time will doubtless come—many years hence—when very little coal will be burned in the raw state. There will doubtless be processing of coal by different methods whereby the by-products will be utilized and gas and coke will be available for fuel. However, we must have smoke abatement now and must learn to burn the fuels that are available today in equipment already installed.

The best way to stop smoke is to watch the smoker. Many fireman and janitors know how to prevent a great deal of the smoke they make, but when no one is watching them they become careless. If the fireman or janitor knows that he is being watched, he will take more pains and use more care in the operation of his plant. The territory should be constantly supervised. Our plan in St. Louis is to divide the entire territory into districts with a supervisor in charge of each. Under each supervisor will be three or four instructors, each assigned to a smaller district. Each one of these men will work in his particular district and familiarize himself with smoke conditions; he will watch for the smokers and continuously follow them up, reminding them of the smoke conditions. This man will also give firing instructions to every one in the district, coöperating with all operators of heating plants. Although such men can and will make observations on high-pressure plants, actual negotiations with owners or operators of high-pressure plants should be carried on by a competent engineer able to understand and discuss the problem intelligently.

Conduct of a Smoke-Abatement Campaign

The campaign must be in charge of an able executive secretary, who should be not only an engineer, well versed in the science of combustion and its practical application to various kinds of heating and high-pressure equipment, but must be a man who can command the support of the engineers of the city, and the various organizations previously interested in smoke abatement, and must be able to organize these forces together with the various industries, furnace manufacturers, fuel distributers, etc., who are directly interested in or affected by smoke abatement, into a harmonious civic body, in which all can work together for the common good.

Where a city has a large problem in smoke abatement, such as St. Louis has, with its low wind velocity and its 95 per cent bituminous coal, it is advisable that the League employ for a time a consulting engineer who has specialized in smoke abatement and who can bring to the city the experience of other cities in this problem, and so avoid their mistakes.

It seems needless to again emphasize the fact that the efforts must be continuous. The supervision over the territory, publicity, educational work, and other phases of the campaign must be carried on continuously. It has been proved in other cities, especially in Salt Lake City, that any let-up in the work immediately results in a decided setback in the progress of the campaign. Smoke abatement must be considered as a major municipal house-keeping problem with a comprehensive organization devoting their efforts continuously to the problem.

Monetary Loss Caused by Smoke Appalling

The actual monetary loss caused by smoke is appalling. The waste of fuel in this country due to imperfect combustion is conservatively estimated at sixty million tons a year, more than enough to supply the city of Chicago. In an American city having a serious smoke problem, the actual damage traceable directly to smoke runs from $15 to $20 per capita each year, without taking into account its effects on health. The Department of Commerce estimates that smoke costs the United States five hundred million dollars annually. These tremendous losses are unnecessary and inexcusable in this enlightened age and it is time something was done.

A smoke-abatement organization should help the industries of a city; help them to grow and prosper; help to build up and enlarge a city so that there will be more stores, factories, hotels, and businesses of every kind. A properly carried-out smoke-abatement campaign is the most profitable enterprise in which a city can engage. A successful campaign will not only be profitable financially to a community, but it will bring a purer atmosphere and consequently better health conditions for the people, especially for children. It will lead to fuel conservation and the installation of better equipment. People will get better results from, and will be better satisfied with their fuel and their heating and power-plant equipment. The St. Louis Smoke Abatement League wants to make St. Louis the best place in the world to live in, both from a health and a business standpoint. It can be done—by coöperation and team work and the proper recognition of the rights of the other fellow.

This is a public service which the engineer should perform. He owes this not only to his profession, but to his fellow-citizens. With the congestion of humanity in our cities, special problems arise that the engineer, and only the engineer, can cope with. Engineers must never forget that they have a special obligation to the public. They should always feel that it is their special privilege by virtue of the knowledge which they have, which no other group in the community has, to make life profitable.

Wrought-Steel Steam Valves

THESE valves are being made by Dewrance & Co., Ltd., of 165 Great Dover Street, London, S. E. 1. The bodies are solid drop forgings of steel machined out to provide the necessary passages for the steam. After being forged to their exterior form the bodies are thoroughly normalized to remove any internal stresses and are then bored, drilled, faced and generally machined to produce the final shape.

It is a comparatively simple matter to bore out the parallel slide valve from a solid forging, while in the case of the stopvalve the passages may be produced by angular drilling. Apropos of the latter operation, it will be seen that there is inevitably a difference in the wall thickness on opposite sides of the steam passage; but, in view of the fact that the metal is wrought, not cast, this feature produces no difficulties on account of changes in temperature.

Both the valves and their seatings are of a nickel alloy which is very resistant to erosion and corrosion, and in the larger sizes the seatings are cast centrifugally. The seatings are screwed into the bodies and are provided with lugs for the engagement of a tool if it is necessary to withdraw them for overhaul. In this connection the makers state that even after prolonged service at high temperatures, there is no great difficulty in unscrewing these seatings.

The spindles of these valves are of forged mild steel, nickeled on the surface, and the only exceptions to the use of wrought material throughout the construction of the valve, are the hand wheel, of cast iron, the nut, and the gland, both of which are of bronze.—*The Engineer*, September 16, 1927, p. 320.

Comparison of Hydraulic Formulas and Theories

A Discussion of Specific Characteristics for Hydraulic Turbines, and Comparison and Limitations of Various Water-Hammer Theories

THREE papers were presented at the Hydraulic Session of the Spring Meeting of the Society, held in White Sulphur Springs, W. Va., May 23 to 26, 1927, two of which, being of a theoretical nature, provoked considerable discussion, both written and oral. All papers presented at this session appeared in the Mid-May, 1927, issue of MECHANICAL ENGINEERING. The first paper, that by W. S. Lee,[1] on Rack Structures and Headgates of Cedar Creek Hydroelectric Plant, was presented in abstract, and owing to its descriptive nature no discussion resulted. In the second paper, Specific Characteristics for Hydraulic Turbines, by Arnold Pfau,[2] the author suggested a new expression for specific speed that is non-dimensional and embraces the three fundamental characteristics of a turbine, namely, peripheral-speed coefficient, velocity-of-flow coefficient, and efficiency. The paper proved very interesting as was indicated by the eagerness with which it was discussed. The discussion opened with the written comments of H. Birchard Taylor,[3] which, in the absence of the writer, were presented by L. F. Moody.[4]

While he considered it of interest and value to show how the specific-speed characteristic might be split up into the product of a series of ratios, together with a numerical coefficient depending on the system of units used, Mr. Taylor did not see any practical advantage in departing from the basis of expressing specific speed, merely for the purpose of securing a non-dimensional quantity. On the contrary, he believed that this would introduce confusion, since it would destroy the standardized practice which had already been secured by the general adoption of the method universally used.

At the time the specific-speed conception was first originated, he said, there were various methods proposed for expressing the speed characteristic of a turbine. One of these was the use of a "specific power," resulting in numbers which varied as the square of the specific speed, but providing a characteristic which would have served the same purpose as the commonly used specific-speed term. The specific-speed relation having been first introduced in Europe and having been expressed in the metric system, the engineers of his company had proposed to adhere to the metric system in expressing specific speed for the purpose of promoting international standardization. Later, however, the use of specific speed expressed in English units began to be followed in American practice, until it had become common practice to express it in both systems of units. This practice, however, did not cause any great inconvenience, he explained, since the conversion from one system to another involved nothing more than multiplying by a single constant. Merely for the sake of standardization, however, he did not believe that the introduction of a non-dimensional quantity in place of the commonly used specific speed would have much chance of general adoption, since the practical effect would undoubtedly be to introduce a third method of specifying the specific speed in addition to the two in use. Whenever an international standard was required, he argued, it would be far simpler and more convenient to use the metric value. If it were desired to introduce the specific speed as a product of a series of ratios along the line of Mr. Pfau's paper, this could readily be done with existing values of specific speed merely by retaining among the component terms the dimensional factor which remained a constant for any one system of units. Of course, he added the specific-speed characteristic might be split up in various ways, depending upon the particular diameters, velocity factors, etc., which it might be desired to introduce.

Although he did not know whether Mr. Pfau would advocate the introduction of another method of expressing specific speed in ordinary practice, or whether he merely intended to show how this characteristic could be expressed non-dimensionally, he urged that in any case the complications which would result from introducing another system in ordinary practice be avoided, since this would merely require the use of an additional factor every time it became necessary to calculate the specific speed for any particular case, and this additional operation would not lead to a result having any greater significance than the value of specific speed as commonly expressed.

Mr. Moody then in a discussion of his own preparation said that while he appreciated the value of analyses of the dimensional relations of hydraulic machines such as presented by Mr. Pfau, since it was both interesting and useful to show how the quantities which entered into the specific-speed relation might be grouped in one of a number of ways, nevertheless he was not prepared to agree with Mr. Pfau that, to use his words, "The objection raised by Bruno Eck—that the characteristic (or specific) speed is not non-dimensional—is justified." Neither from Mr. Eck's paper nor from Mr. Pfau's did he get any clear reason as to why the substitution of a non-dimensional number for the existing specific-speed quantity would have any practical advantages or be of any actual assistance in computations. His reactions were quite the reverse, and he felt that the replacement of the specific-speed basis which had become standard practice would merely cause confusion and add unnecessary complication. He did not feel that the existing specific speed needed any apology for not being non-dimensional—one might use many factors and terms which were not pure numbers but must be expressed in a particular system of units, and he considered this no handicap in their use. The great value of specific speed as used, he explained, was that it had become well standardized and values expressed in that standard system were well understood everywhere. Although the usage was, in some particulars, conventional, it was in no way illogical, and for the very reason that it involved only the variables of most usual occurrence and applied them in their customary units of expression, it was of the greatest service in all work in the hydraulic field.

Continuing, he explained that the specific-speed function might be expressed in the form $n = n_s H^{5/4}/\sqrt{(\text{hp.})}$ as generally used, where n_s was a constant for a given type or design of turbine, whatever its size or the head under which it operated, and this constant was the specific speed.

There had been suggested at various times, he said, other methods of expressing the same relation. As an example, he referred to Professor Mead's book on water power, wherein was proposed what amounted to a "specific power," or hp. = (const.) $H^{5/2}/n^2$. Professor Mead's constant would be the square of specific speed, and although less convenient on account of the large numerical values, it involved exactly the same relation and would serve the same purpose.

If it were the custom to specify turbines for a given quantity of water, rather than horsepower output, then the more convenient relation would be $n = n_s H^{3/4}/\sqrt{(Q)}$, which, he explained, was the form used for pumps. He stated that he had not been altogether free from the tendency to introduce new systems, since for the purpose of developing the inter-relations between pumps and turbines, he had applied the pump specific speed to turbines.

There were any number of ways of expressing this dimensional relation, he said; for example, one might use a "specific head," H_s, or the head required to give one r.p.m. of a 1-hp. turbine:

$$H = H_s\ (\text{hp.})^{2/5} n^{4/5};\ \text{where } H_s \text{ would be } 1/n_s^{4/5}.$$

Dr. Thoma, in what he considered an otherwise admirable paper, had proposed another system, using angular velocity in radians instead of r.p.m. Dr. Eck had suggested "three possible non-

[1] Vice-President and Chief Engineer, Southern Power Company. Mem. A.S.M.E.

[2] Consulting Engineer, Hydraulic Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

[3] Vice-President, I. P. Morris Corporation, Philadelphia, Pa. Mem. A.S.M.E.

[4] Consulting Engineer, I. P. Morris Corporation, Philadelphia, Pa. Mem. A.S.M.E.

dimensional coefficients" for thrust, pitch, and another specific speed; and Mr. Pfau in his paper, proposed still another.

In a recent issue of *Wasserkraft*, Mr. Rindl, the editor, had presented what the writer considered a most pertinent discussion of this subject. He closed his discussion by appending a free translation of a portion of the paper Zur Spezifischen Drehzahl Hydraulischen Maschinen,[5] which he explained, expressed views which he shared. The translation follows:

> The particular practical purpose of the speed characteristic does not require its being dimensionless, since other equally important quantities used for comparison are not dimensionless, and since furthermore only a limited class of hydraulic machines involves the theory of propellers or of aerodynamics.
>
> Among the numerical characteristics used for characterizing typical properties, the characteristic in customary use for hydraulic machines is indeed most complicated, because the design values entering into the expression for the characteristic number depend upon three factors—the number of revolutions, power, and head—while elsewhere there is almost always presented a function of two variables, as for example, in electrical machinery. For 25 years in the field of hydraulic machines it has been customary to use as a characteristic the conversion of the speed to a power of 1 hp., as the usual technical unit of power, and to a head of 1 meter. This was first introduced by Camerer for hydraulic-power-generating machines (turbined) and then also applied to hydraulic power-absorbing machines (centrifugal pumps).
>
> The purpose of such characteristic numbers—and for this reason the recent proposals for the introduction of other characteristic numbers must be thrown out of court—is not the coördination of operation and theory, not the referring of design values to theoretical foundations, but solely the simple practical purpose of the quick comparison of measurable conditions of operation and the dimensions of the installation.
>
> From this requirement it immediately arises that the characteristic number must be expressed in the units of the technical system of measures which is customary in the measurement of power and dimensions. It appears useless, and the comparison with foreign literature, that is, with data in the English system of measures, is not in the least facilitated, if in place of the specific-speed quantity of our technical system of measures (m-kg-sec.) a dimensionless characteristic is proposed, since nevertheless all the design dimensions from the head to the characteristic diameters—and even the power in horsepower—and all velocities, must be converted. . .If further comparisons of different installations are to be made, a reconversion of the dimensionless characteristic to the basis of the head and power according to our system of measures, that is to the specific speed of the m-kg-sec. system, is still indispensable. . .Thus, if one desires to keep the specific speed dimensionless, no conversions are abolished, but on the contrary these dimensionless speed or angular-velocity characteristics must still be reconverted into specific speed, in order that we may be able to determine the relation with all customary quantities. . .
>
> The specific speed $n_s = n_1\sqrt{N_1}$ will therefore be defended not only because it has been in use for 25 years; a change to another characteristic is justified only if it is more simply handled; and this is, with all the proposals so far made, not the case under the requirements of practice, which wants to compare only directly measurable quantities, and from the comparison to obtain directly measurable quantities. . .

L. F. Harza[6] wrote that he had carefully studied Mr. Pfau's paper and was convinced that his point was well taken, also that American hydraulic engineers, as well as foreign engineers, should adopt the non-dimensional coefficient of speed proposed in lieu of the former dimensional coefficient.

The author, he said, had brought out the fact that in any dimensional system there was a constant ratio between specific speed as it was used and the new coefficient which he proposed; therefore, he pointed out, the new coefficient did not involve any new conception nor did it indicate any different characteristics of the turbine than the previous specific speed. In fact, he said, it was as truly the specific speed as the former coefficient, except expressed in a different unit, since it had a constant ratio to the old coefficient.

The fact that the old coefficient of specific speed represented the speed of a one-horsepower turbine of homologous design operating under a head of one foot was of itself of no value whatever as a mental conception, according to the writer, for the reason that the size of turbine and operating head mentioned was outside of the range of usefulness. In his own personal use of this constant he had seldom referred back to the above definition of its meaning except when required to explain its meaning. In other words, he added, the use of the constant did not require keeping in mind its dimensional definition. He was of the opinion that other users of the constant had experienced the same mental processes and had merely learned that a specific speed of 100 represented approximately the upper limits of speed of a Francis type of turbine and likewise had formed a mental estimate of the approximate specific speed best adapted to the usual range of heads.

He believed that the only disadvantage which would be experienced by the hydraulic engineer by adopting the new coefficient would be to revise his mental picture of magnitude. In other words, he explained, it would be necessary to learn to think in a new unit. He would be required to know that his old conception of 100 as approximate limit of speed of a Francis turbine had become 0.893—or better, as suggested by the author 89.3—and that other specific speeds in which he was accustomed to thinking required revision proportionately.

Thus the new constant was the old constant divided by 111.913, or by 1.11913, and if one did not wish to change his mental conception of the meaning of this constant he could think of it as the speed of a 1-hp. turbine of homologous design, operating under a 1-ft. head, divided by the above constant.

The writer considered the opportunities in science and engineering for the adoption of constants which were common to both the metric and American system of weights and measures so few in number that when such an opportunity existed, as in the case at hand, it should by all means be adopted, thus providing an international unit and dispensing with the need of conversion factors.

He saw no need, however, of giving this constant a new name. It was as truly an indication of relative speed or "specific speed" for a given power capacity and given head as the older constant. He did not like the term "specific characteristic" because there were several other characteristics of a turbine while this one was purely a speed characteristic. The elements which made it so were all involved in the author's formula in the terms V^x, v^x and e, he explained. Even though these elements of the formula did not refer to horsepower and feet of head as such, yet the result would be the same as that following application of the old formula and dividing by a constant. He saw no need of a new name, but added that if he were overruled by the opinion of the majority he would suggest "speed characteristic" instead of "specific characteristic."

Assuming the adoption of the new speed characteristic, the question arising, he pointed out, would be as to the best method of computing it. If computed by the author's formula, using $u^x\sqrt{V^z}$, one would be faced by the fact that different manufacturers measured D at different places on a Francis runner, the position being arbitrary. The effect of this canceled out in the product $u^x\sqrt{V^z}$, he explained, but nevertheless tended to confuse the mental conception of magnitudes and its interpretation. However, the way was open to use either the old method and divide by the constant or use either of the author's formulas.

In a fourth written discussion, submitted by Robert W. Angus,[7] the writer stated that one very great advantage of the existing specific speed was that the formula contained the speed, power, and head under which the turbine operated; these being the three factors always available in selecting the turbine, and the combination of the three gave the specific speed, and hence the type and size of the machine.

He considered the term "specific speed" misleading, some such expression as "type characteristic" more nearly meeting his favor. Referring to the first sentence in the second paragraph of Mr. Pfau's paper, where it was stated that the specific speed was a number of revolutions per minute, he explained that that could not be correct, for if it were, the specific speed would be dependent on the unit of time only, and not on the other units, and if the minute were adopted, the specific speed would be the same for all systems of units. Making N and H equal to unity could not change the units involved in n_s.

Continuing, he pointed out that, specific speed being a function of n, N, and H had the units

$$\frac{\text{revs.}}{\text{time}}\sqrt{\frac{\text{force} \times \text{length}}{\text{time}}} \times \frac{1}{(\text{length})^{5/4}} = \frac{\text{revs.} \times (\text{weight})^{1/2}}{(\text{time})^{3/2} \times (\text{length})^{7/4}}$$

Comparing the values of n_s in the English and metric systems and

[5] *Wasserkraft und Wasserwirtschaft*, Apr. 15, 1927, p. 114.

[6] Hydraulic Engineer, Chicago, Ill. Mem. A.S.M.E.

[7] Professor of Mechanical Engineering, University of Toronto. Mem. A.S.M.E.

introducing the definition of one horsepower as 550 ft-lb. per sec., or 75 kg-m. per sec.,

$$\frac{n_s(\text{English})}{n_s(\text{metric})} = \frac{(2.2046)^{1/2}}{(3.2808)^{3/4}} \times \left(\frac{75}{550}\right)^{1/2} = \frac{1}{4.445}$$ as given by Mr. Pfau.

Clearly, he said, the unit of n_s was not revolutions per minute, even when both the power and the head were unity. Further, he added, when the relation between the values of the specific speed in the different systems was so simple, there appeared to be little objection, from the practical standpoint, to using either system.

The notation of Mr. Pfau being unusual, he introduced the usual value ϕ for the coefficient of peripheral speed, and c_v for the coefficient of velocity, these values corresponding to u^x and V^x, respectively, of the author. Practice, he said, had shown that ϕ was related to the specific speed, and, in a measure, the value of ϕ also indicated the type of wheel and its size, although not directly with reference to the power, speed, and head. The author, however, he pointed out, proposed to combine φ with c_v and the efficiency e, so as to make the quantity $\phi \sqrt{e \times C_v}$ the specific characteristic.

The coefficient of velocity, he explained, might be shown to depend upon the square root of the efficiency and on the angles in the turbine, and hence, for a set of similar wheels of different size, the value $\sqrt{e \times C_v}$ was a function of the efficiency only. It was well known from theory and practice, he said, that the efficiency depended, among other things, on the size of the machine, as well as on the grade of finish and construction and design, for friction was a function of the hydraulic radius of the guide passages, and that radius would increase as the wheels were increased in size, even though they were made exactly similar. Hence, since the value of the proposed characteristic depended upon the size of the unit in each case, it could not be looked upon as an indicator of the type of wheel only.

Of course, he said, it was true that the variations in the efficiency would not be great in good practice, and the variations of the square root of the efficiency would be still less, and therefore the value of the characteristic would be almost entirely controlled by ϕ and C_v, yet the characteristic to be a true indicator should be independent of the size. It would appear, he added, that the gain obtained by making the characteristic a pure number was further counterbalanced by its separation from the head, power, and speed of the turbine.

Commenting orally on the paper, George A. Orrok[8] stated that, very unfortunately, in most of these characteristics all one needed to do when laying out a part was to put the English characteristic itself on the bottom or the top, and the metric number on the other. A bad feature was the difference in the horsepower, and it appeared to the speaker that there was an approach toward the dropping the term "horsepower" in favor of kilowatts, which was a real power unit, whereas horsepower was only a half-caste sort of unit. He favored such a move.

The International Electric Technical Commission, the Committee on the Rating of Rivers, and a number of other international committees, he said, were all standardizing on the use of the kilowatt instead of the horsepower. He did not consider the use of a non-dimensional characteristic good practice, and added that his own personal feelings were in favor of the actual dimensional characteristic and the quick translation which these conversion factors permitted.

At this point the Chairman, R. L. Daugherty,[9] stated that, from the practical utilitarian standpoint, he felt that the old conception of specific speed was the most useful. The average engineer in dealing with a hydraulic turbine, he said, was most concerned with the power, the rotating speed, and the head: the three fundamentals. They did not involve any details of design. The old specific-speed expression involved those three most important practical considerations, he pointed out, and he did not see any possibility of dropping it.

If the new plan were adopted, engineers would compute the specific speed in the old way and then divide it by the new, and as the speaker considered it, very inconvenient number as a conversion factor.

He doubted that in practical use one would get back to the coefficients suggested by Mr. Pfau, because they involve considerable work at the drafting board.

Mr. Pfau's presentation of a new form for another method of expressing specific speed might, he felt, be extremely useful for certain purposes. Several such forms suggested by Mr. Moody were considered by the speaker extremely interesting and valuable at times and showed the limitations under which a designer might have to work. He regarded all of them as alternate special forms of great use in specific fields, but not as substitutes for the conventional specific speed.

He could see the desirability of having a non-dimensional unit in many cases, yet that did not remove the desirability of having dimensional units. He mentioned a simple analogy in the common use of the term "specific gravity," a term which would never be discarded from engineering literature.

When using specific gravity, he explained, the practice was to refer to either water or air as a standard, and that at once tied in something involving dimensions. He looked upon the suggested unit as somewhat similar in that, being non-dimensional itself, one must always relate to other quantities involving dimensions before any real practical use could be made of it.

He was not especially concerned with the type of unit, that is, whether English or metric, nor did he prefer either horsepower or kilowatts. He reminded his hearers that in stating his definition of specific speed he had mentioned power and rotating speed and head. Those, he said, were the important quantities.

As to the trouble resulting from the use of a double system, he explained that the conversion factor, the value of which we all knew, could simply be used in the formula to introduce either the metric or the English system as desired. However, that in itself did not seem of very great importance. Regarding the name of the quantity, he felt that the term "specific speed" was possibly not the very best, yet it had been generally accepted, and since it brought in rotative speed as the most fundamental term when reduced down to a physical conception, he felt that it might just as well be adhered to. But it should be frankly recognized that it was not really speed that was under discussion, but a number which showed the type to which a turbine belonged, and, for that reason, something involving the type, such as "type characteristic," would be a very acceptable term.

Commenting on the reference to efficiency as "mechanical efficiency," the speaker expressed the belief that if the analogies to the different efficiencies mentioned in connection with the steam engines were regarded the mechanical efficiency of a turbine was only a ratio of the power actually developed by the water in the runner to the power output, and the difference between the two brought in only the mechanical friction of the shaft in its bearings and similar quantities. This efficiency, then was the overall efficiency; in other words, the product of mechanical efficiency times hydraulic efficiency times another ratio, which would involve leakage in the case of a reaction turbine.

Robert Cramer,[10] who presented the paper in the author's absence, quoted from the last paragraph of Mr. Eck's paper already referred to, what he considered a very appropriate statement, as follows: "Whether it is expedient to introduce this non-dimensional coefficient is ultimately a matter for practical engineers to decide."

The attempt to reduce almost every important engineering question to the abstract number was a tendency as old as engineering, he reminded his hearers, but the practical building of machinery and putting it in operation had always preceded theory in every branch of engineering.

In referring to his own experience in the development of steam engines, he recalled the first discussion of the term "entropy." Every practical engineer discarded it as a term of no practical value; but the steam engineer had learned to work with it in a manner which was just as practical as that in which he used "pounds per square inch."

The Chairman felt that while numbers characterizing the design of hydraulic machines might appear very theoretical at first, there

[8] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[9] Professor of Mechanical and Hydraulic Engineering, California Institute of Technology, Pasadena, Cal. Mem. A.S.M.E.

[10] Consulting Engineer, Milwaukee, Wis. Mem. A.S.M.E.

might be some value in them which would come out gradually as the designer became accustomed to using them. It was not important, he argued, that a basis of a system be something abstract and absolute; that basis must be uniformly applied.

In a written closure, Mr. Pfau stated that it had not been his intention to advocate a "new" method of expressing specific speed, but rather to point out a way as to how "specific speed" could be more accurately defined and made more universally understood and applied. Mr. Cramer, in presenting the paper had most precisely expressed his viewpoint in his regarding the expediency of introducing this non-dimensional (and it might be added, more correct) coefficient, being ultimately a matter for practical engineers to decide, and he submitted to such decision, not, however, without calling attention once more, to the incompleteness of the fundamental and practical structure of the present term "specific speed." This definition might create a misleading effect on account of its being "unaffected by efficiency."

$$n_s = n \frac{(N)^{1/2}}{(H)^{5/4}}$$

The runaway speed n_r of a turbine, Mr. Pfau continued, was the speed at which the efficiency had become zero, i.e., at which "no power" was obtainable or, in still other words, at which the turbine as an energy or income producer became worthless.

For a fixed (commercial) speed n, the head H_r might be that head at which the turbine must operate under runaway conditions (zero power, zero efficiency) in order to maintain the commercial speed.

Assuming a runaway $n_r = 2n$, the present formula $n_s = n \times \frac{(N)^{1/2}}{(H)^{5/4}}$ then turned into $n_{sr} = 0$, because $N = 0$. Similarly his new term became zero, since $e = 0$, consequently

$$n_{sr} = 2\, u^* \sqrt{v^*}\, \sqrt{0} = 0$$

Assuming, however, a value of n between normal speed and runaway, with N a fixed value; then, for instance, a speed n 60 per cent above normal with, say, a reduction in output N of 19 per cent but an efficiency of only half of its former value, showed a marked difference between the actual values of the two terms.

$$n'_s = \frac{1{,}6\, n\, (0.81N)^{1/2}}{(H)^{5/4}} = n_s \times 1.44$$

However, the new term

$$n_s{}^{*\prime} = 1.6\, u^* \sqrt{v^*}\, \sqrt{0.5\, e} = n_s{}^* 1.13,$$

(with some runners the discharge was not affected by a variation of the speed), or a difference of fully 27 per cent.

It could be thus seen that his new term $n_s{}^*$ by introducing the efficiency presented unscrupulous statements of "high efficiency attainments" when secured by merely overspeeding the turbine at the expense of its efficiency.

The final paper of the session was that by Ray S. Quick[11] on Comparison and Limitations of Various Water-Hammer Theories, in which the author confirmed the accuracy of the elastic-water-column theory by presenting experimental test data, and gave charts for graphically solving problems of maximum pressure rise with uniform gate motion and complete closure. In this case also the author was unable to be present, and L. F. Moody presented the paper in abstract, following which it was thrown open to discussion from the floor. The first written contribution was by W. S. Merrill,[12] who commented upon the great importance of the question of water hammer to the engineer engaged in the design and construction of hydroelectric plants having penstocks and flow lines.

Mr. Merrill mentioned in passing Allievi's Theory of Water Hammer, written in Italian, and translated by E. E. Halmos, in 1925. The work was in two parts, text and figures, and both were full and complete. Although, as he pointed out, the average engineer had not studied or had forgotten much of the mathematics used in the text, he would find it extremely interesting and instructive. He also referred to Creager and Justin's Hydroelectric Handbook, issued early in 1927, containing a chapter on water hammer written by Mr. Creager and Mr. Halmos. It also discussed the application of the Allievi theory to penstock and flow-line problems.

Although the hydroelectric engineer was interested in the theory of water hammer, he said, he was more directly interested in its application to particular cases, and these probably would not be the simple one discussed by the author. Penstocks and flow lines, in addition to varying in size and thickness, varied in material from which they were made. For instance, a flow line might be of steel pipe, wood-stave pipe, concrete pipe, concrete tunnel, concrete-lined tunnel, and steel pipe embedded in concrete in the tunnel, or it might be a combination of one or more of the above materials. Penstocks might be of steel, concrete-lined tunnel, steel pipe in concrete tunnel, etc. Mentioning the author's discussion of the method of determining L, A, and a for lines of varying size, he said that Creager and Justin also gave examples of the application of the theory and showed ways of applying it for other than the usual simple case. These authors had recommended that the computed result be multiplied by a factor varying from 1.0 to 1.50, to cover the uncertainties of applying the theory to complicated penstocks and pipe lines. It would be of very great value, he said, to have additional experiments to prove the application of the theory to these complicated, but usual, cases.

The writer considered a knowledge of the negative water hammer caused by opening of the gates or valves, and also the negative swing of the positive water hammer, equally as important as the upward or positive water hammer. Both of these negative pressures were considered very important, especially when flow lines or penstocks had vertical curves which might fall below the hydraulic gradient under the extreme water-hammer conditions mentioned.

Since he felt that Mr. Quick's paper and Creager and Justin's Handbook were likely to be extensively used in solving water-hammer problems, he believed that it would be well to call attention to a slight discrepancy between the value of one of the terms used in Mr. Quick's nomenclature and the corresponding term used by Creager and Justin. In Mr. Quick's nomenclature H_0 represented the initial steady head near the gate corresponding to V_0. Creager and Justin's y, in the case of a pipe line opening from a forebay, represented the vertical distance between the forebay level and the tailrace. In the case of a surge tank it represented the difference between the elevation of the water in the surge-tank riser during the period of steady flow before the gate was closed and the tailrace level. In the case of the surge tank it would be seen that there was a discrepancy between the two which corresponded to the friction between the surge tank and the gate. Since Mr. Quick had stated that he did not consider friction, this difference, he explained, was apparently intentional. He believed that Mr. Quick was in error and that Creager and Justin were correct. Agreement should be had as to what level should be used to represent correctly the head to which the water hammer was to be added.

Creager and Justin, in giving an example of the decrease in pressure due to gate opening had used $y = 300$ ft., as in the other examples. This represented the distance of the "static gradient" above tailwater. This was shown in a figure illustrating the work as the same identical line as that one used for the level of the water in the tank (riser) when flowing at a velocity V_0. It was apparent, he said, that they were likely to be considerably different for many cases.

The term T used by Mr. Quick for the time of gate-closure travel would be commonly taken as the total time of closing the turbine gates or valves, he pointed out. However, he added, it was known that in the case of the turbine governors the gate travel in some portions of the stroke was more rapid than the average rate of speed of the complete stroke, owing to relatively slow motion at the start and finish of the stroke. For gate closure the maximum rate of movement had a bearing on the total water hammer. To simplify the application of the theory there should be used a reduced value of T corresponding to the time of gate operation if the gate moved throughout the stroke at a constant rate equal to the maximum rate. The I. P. Morris Corporation, he said, recommended the use of 85 per cent of the nominal value of T for gate closure, conforming to the ratio of the average rate of speed of their governors

[11] Engineering Department, Pelton Water Wheel Co. Assoc-Mem. A.S.M.E.

[12] Assistant Engineer, Electric Bond & Share Co., New York, N. Y.

to the rate of speed of the critical portion of the stroke. For gate opening they recommended using 100 per cent of the maximum normal speed. The percentage to be used for gate closure probably would vary for governors manufactured by different companies, he said, and added that experiments by manufacturers or utilities would be of great value in determining the proper percentage to be used.

He pointed out that Mr. Quick's chart for finding the maximum water hammer for gate closure was similar to that shown by Allievi and Creager and Justin except that it was inverted. It would have added to the value of the chart, he argued, if Mr. Quick had numbered the dotted lines representing the s curves. In connection with the curves he called attention to the fact that Mr. Quick's symbol V_0 corresponded to Creager and Justin's symbol v, while his H_0 corresponded to their y.

On Mr. Quick's chart for maximum water hammer, Fig. 5, he felt that it would have been well to have designated by some symbol the figures representing the different values of $(H_0 + h)/H_0$. In Creager and Justin this wascalled $Xi^{2h} = (Xi^2 \times H_0) - H_0$.

In concluding this comment, Mr. Merrill said that further experiments to confirm the theory for other conditions of head and length of pipe were very desirable.

W. P. Creager[13] commented in writing on the notable fact that, despite all that had been published regarding the extreme inaccuracies of the so-called "approximate" formulas for water hammer, some engineers still used them for important investigations. He was sure that this practice would not be prevalent among those who studied Mr. Quick's paper in which he considered the errors in the approximate formulas extremely well depicted.

He pointed out that the standard Allievi chart reproduced in the author's Fig. 5 was limited to an N of 20 and a K of 8. The writer had had a number of problems which were for outside the limits of that chart, and the chart was not capable of extrapolation at its extremes. It is for this reason, he explained, that he was glad to have the use of the author's Fig. 3 which gave the same information as Allievi's chart but was extended to an N of 50 and a K of 40, which he felt should be well within the range of ordinary problems.

Although several formulas had been published for the value of the velocity of wave propagation, a, in wood-stave pipe, the writer had determined from experiments that they were not at all reliable. In fact, it did not seem possible to determine the value of a for wood-stave pipe. The difficulty of combining the elasticity of the water, staves against adjacent staves, staves against bands, and bands seemed unsurmountable, particularly as it involved the elasticity of the wood where it was crushed against the bands, i.e., the elasticity beyond the elastic limit.

Values of a for wood-stave pipe as low as 250 had been observed, he said, and it was his opinion that a tabulation of all available experimental values would be of great interest.

L. F. Harza, also writing, referred to the work of the author as a very valuable service to the profession in that he had determined the limitation and inaccuracies of the various approximate formulas for water hammer as compared with the more accurate theory usually known as the elastic-water-column theory. He had also performed a very valuable service, he felt, in developing diagrams for the solution of problems in the application of the elastic-water-column theory with reasonable facility and speed.

However, he did not consider it at all surprising that the author should find that the elastic-water-column theory, which was nearly correct in its assumption, agreed much more closely with experimental results than the approximate formulas. The apparent divergence between theory and practice was often used as a discredit to the engineering profession, he said, adding that, in reality, true theory and practice must exactly agree. Facts showed that theories were incomplete or based upon inaccurate or approximate assumptions if divergence was apparent.

He did not consider the use of approximate methods often justified except in cases where the exact formulas were so complicated and tedious of application and differed so little from the approximate results as not to justify the additional time and work involved. But the use of approximate formulas, even in that case, was not justified unless and until a detailed comparison throughout the range of practical application had been made by some one in order to establish the degree of accuracy of the approximate formulas.

This service, he said, Mr. Quick had performed and instead of indicating that the approximate formulas were sufficiently accurate his analysis tended in general to discredit them, except for a narrow range of usefulness. In supplying diagrams for application of the elastic-water-column theory he had made this problem so easy as to eliminate entirely the need of ever resorting to the more approximate method.

Further written discussion was submitted by Minton M. Warren[14] in which he said that Equation [7] seemed to give accurate results, not only as checked by the most accurate theory available, but also by actual experiments. Continuing, he said that twelve years ago when he had prepared a similar paper[15] to compare the existing formulas on water hammer, the literature on the subject in English was very meager and the experimental data practically nil. Since that time a wealth of formulas and literature had sprung up, and as the subject was rather complicated and not of every-day interest, the engineer designing a pipe line against this force was bewildered by a formidable array of rather complicated mathematical equations, many of which were wrong and often gave results differing by 100 per cent.

With the knowledge of the subject gained in the last ten years, it seemed to the writer that certain of the approximate formulas should be discarded as definitely incorrect, leaving one simple formula for use in preliminary quick calculations and a more exact formula for final pipe design.

Quick Closing of Gates. All writers agreed, he said, that for times of gate closing less than $2L/a$, the formula for maximum water hammer and maximum possible pressure rise in the pipe was

$$h = \frac{a\ V_0}{g} \qquad [1]$$

Unless the shape of the pressure curve was required, this formula was preferable to all others, and eliminated the elaborate calculations required for plotting Fig. 12 by using Equation [7]. It gave exactly the same numerical result with a few settings of the slide rule, which the more complicated formula gave with considerable time and labor.

He advocated abandoning the use of complicated formulas for times of gate closing less than $2L/a$, for not only did they take more time, but they also might give incorrect results; in some cases too small, and in other cases, above the absolute maximum pressure, which it was known could not be exceeded in practice.

Slow Closing of Gates. In cases where the gate was closed in a time longer than $2L/a$, the writer explained that the physical conditions in the pipe were too complicated to be expressed by any simple formula. This was due to the fact that the initial pressure wave caused by starting the closing of the gate had had time to run up the pipe to the reservoir and back to the gate, there to be reflected again, thus decreasing the pressure due to the gate closing.

Although it was certain that no simple formula could exactly allow for this reflection, it seemed likewise reasonable that even the most complicated formula could not absolutely represent the result which was bound to be different in different cases. For instance, if the gate were closed very slowly, the wave might return to the gate while the gate was still almost wide open with the water still rushing through it at high velocity. In this case the reflection might be different from the case where the gate was almost closed.

It was for this reason, he said, that so-called accurate formulas might not give any more accurate results than the approximate equations, and the mere fact that an equation was complicated and hard to solve did not guarantee the accuracy of its results. For example, he added, in the experiment of Fig. 13, Mr. Quick's Equation [7] gave a maximum rise of 49.1 ft., whereas the writer's equation

$$h = \frac{LV}{g(T - L/a)} \qquad [10]$$

[13] Vice-President and Chief Engineer, Northern New York Utilities, Inc., Watertown, N. Y.

[14] Consulting Engineer, Curtis & Sanger, Boston, Mass.

[15] Trans. Am.Soc.C.E., vol. 79 (1915).

gave a result of 46 ft., or only 3.1 ft. or 6 per cent less than Mr. Quick's equation. The experiment showed a rise of about 55 ft., and therefore Mr. Quick's formula would seem to be of somewhat greater accuracy. In the design of an important pipe line the work involved in solving this formula was probably justified, he admitted, but Equation [10] above would seem sufficiently accurate for most ordinary purposes.

The results of Equation [9] were just double those of Equation [17], and it was self-evident, he argued, that one of these formulas was wrong and should be discarded from textbooks. In the third experiment (Fig. 13), Equation [9] gave results 21 per cent too high, and Equation [17] gave results 36 per cent too low. It was the writer's opinion that neither of these equations was sufficiently accurate for general use, [9] being useful only for values of T very close to $2L/a$, and [17] being useful only for large values of T. In certain cases, either of these equations might give results 50 per cent in error; Formula [10], however, was just as simple to solve, and was much more nearly accurate for all values of T.

Experiments. He felt that the engineering profession was much indebted to Mr. Quick for publishing results of actual experiments on a pipe line; however, since the pipe was only 2.06 in. in diameter and the maximum water velocity was only 1.11 ft. per sec., it would not compare with the size and velocity in pipes of ordinary hydraulic practice where the water hammer was most important. Any conclusions reached from results on such a small pipe and slow velocity, he said, might not apply to larger values, although from the few experiments the writer had seen the same formulas did seem to apply in both cases.

To illustrate, he pointed out that in the first experiment shown by Mr. Quick (Fig. 11), where $T = 0.04$ sec., $V = 0.55$ ft. per sec. Equation [1] applied and gave 74.6 ft., rise as against 80 ft. shown in the test. In the second experiment (Fig. 12) where $T = 1$ sec., $V = 1.11$ ft. per sec., Equation [1] still applied and the result $h = 151$ ft. was the same as Mr. Quick's Equation [7], and tedious calculations of Equation [7] were not required. The test showed about 155 ft. rise.

In connection with the third experiment (Fig. 13), where $T = 3$ sec., the writer gave an interesting comparison of the results by the various formulas as follows:

Equation No.	h	Per cent deviation from test
Test, Fig. 13	55	0
Quick [7]	49	−11 per cent
Warren [10]	46	−16
Johnson, *et al.* [15]	37	−33
Joukovsky and Vensano [9]	70	+21
Impulse and momentum [17]	35	−36

Without knowing the physical conditions of the test, he found it impossible to comment on the accuracy of the value $h = 55$, shown on the graph in Fig. 13. However, he said, it might be stated that if the pressure gage were on the end of a small pipe leading off the main line, it would probably register values of h in excess of the true values, and in this case it might be that Mr. Quick's result of 49 ft. was as nearly accurate as the test result. In any case, he added, it would seem that the only formulas which were sufficiently accurate for use were [7] and [10]. He advocated that the use of the other formulas be discontinued.

Conclusions. In concluding his remarks, Mr. Warren said that literature in English on the subject of the theory of water hammer was so abundant that the average hydraulic engineer had neither the time nor the mathematical knowledge to master all the different formulas. Actual experimental data still seemed to him to be rather meager, and there must be members of the Society closely associated with water-power plants who could run an exhaustive set of tests on a large pipe line varying the velocities and the times of gate closure, and compare the results with the various formulas. This, he felt, would be of the greatest value to the engineering profession, and he hoped that some one would undertake the task.

Until such a test had been run, the writer believed that Equation [1] for quick closing of gates and Equation [10] for slower closing would give results accurate enough for all ordinary purposes, while the more tedious calculation of Equation [7] or some similar theory of elastic water column should be used in the final design of important pipe lines. Equations [9] and [17], he said, should be permanently discarded as not only theoretically wrong, but as not agreeing with any published experiments.

E. B. Strowger[16] wrote that the advisability of ever using an approximate formula for solving water-hammer problems was questionable. He considered it shorter in the end and much more satisfactory to use the elastic-water-column theory. Furthermore, he said, the use of approximate formulas for water hammer was always hazardous in the hands of any one but an expert, and in any event each problem should be investigated to see if it lay within the range of application of the approximate formula in question.

Referring to Equation [7], dealing with quantities at the end of an interval or at a certain proportion of each interval and furnishing a means of calculating pressure rise by a step-by-step process, he pointed out the fact that the factor ϕ took into account the coefficient of discharge of the hydraulic turbine at various values of gate opening. If the turbine were considered as an orifice, he explained, then ϕ took into account the variation in discharge with the gate opening.

Here the writer referred to the paper by Gibson on Pressures in Penstocks Caused by the Gradual Closing of Turbine Gates,[17] in which the following equation was used for the relation between penstock velocity and the water-hammer head:

$$V_n = B_n \sqrt{H_0 + h_n} \qquad [18]$$

In this equation B_n represented the product of a number representing the gate opening multiplied by $-2g$ times the coefficient of discharge of the gate opening. In paper on Speed Changes of Hydraulic Turbines for Sudden Changes of Load, S. L. Kerr and the writer had used this relation in computing the water-hammer head, and for convenience the coefficient of discharge was assumed to be constant throughout the closure, resulting in the supposition that, for a closure with uniform gate motion, the variation of discharge with time for a constant head is linear. This relation, he said, was correct for the assumption of a uniform destruction of velocity and was satisfactory for use in the speed-rise problem referred to, since it had been shown that uniform and non-uniform gate motions, although giving different maximum values of water hammer, produced the same impulse area under the pressure-time curve. However, for an exact solution of water hammer for a given hydroelectric installation, where the gate-discharge relation was known or was readily estimated, his advice was that Equation [5] or Equation [18] with a variable discharge coefficient be used.

To show the difference in the pressure-time curves obtained by first using a varying discharge coefficient and then a constant coefficient, these curves had been computed for one of the 70,000-hp. turbine installations at Niagara Falls.

The given conditions were as follows:

Load dropped = 70,000 hp.

$H_0 = 213.5$ ft. $\qquad a = 4680$ ft. per sec.

$Q_0 = 3160$ c.f.s.

$T = 5$ sec. $\qquad h_{max.} = \dfrac{4680 \times 10.25}{32.2} = 1490$

Penstock length = 690 ft.

Penstock diam. = 21 ft. $\qquad K = \dfrac{1490}{.2 \times 213.5} = 3.489$

$V_0 = 10.25$ ft. per sec.

The curves marked A in Figs. 1 and 2 were based upon Equation [5], and the curves marked B upon Equation [18] and a constant discharge coefficient. The area under the pressure-time curves were the same but the maximum pressure rise in per cent of normal head for the two conditions were 26.2 and 22.7, respectively, giving a difference of 3.5 per cent due to the departure of the gate discharge relation from a straight line.

The author, as had other writers on the subject of water hammer, had assumed throughout his paper that there was no loss in amplitude of the pressure waves. In other words, he said, the pressure waves were not damped. Referring to Figs. 11 and 12 of the paper giving an indication of the magnitude of the damping action in the Big Creek experimental penstock, the writer expressed the opinion that if records were available for a longer

[16] Niagara Falls Power Company.

[17] Trans. A.S.C.E., vol. 83.

time than that given, the rate of damping might be accurately determined and thus knowledge of this phenomenon extended.

J. W. Jourdan[18] and Owen Reed[19] submitted a joint discussion in which they compared results of the author with an actual record of pressure rise in the penstock line of the Balch power plant, recently completed by the San Joaquin Light & Power Corporation as part of its Kings River development, this plant had a static head of 2336 ft., ultimately to be increased to 2391 ft. by raising the height of the diversion dam. The slope length of penstock from surge shaft to power nozzles (see Fig. 3) was 5229 ft. The surge shaft was located 363 ft. back of Anchor No. 1. The penstock proper consisted of a single line ranging from 60 in. to 48 in. in diameter, divided about 300 ft. above the power house into two 34-in. diameter branches. Designed for a discharge of 180 c.f.s., with a net head of 2243 ft., the double overhung impulse-

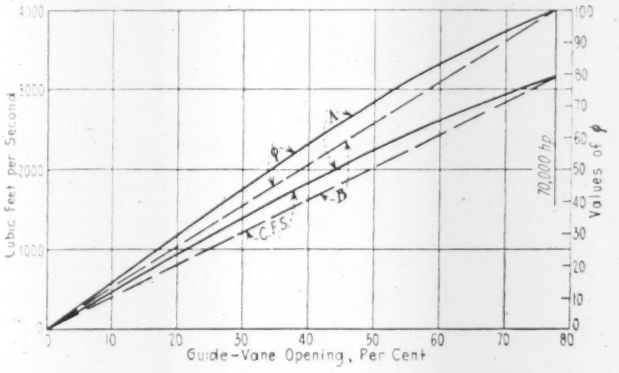


FIG. 1 GATE DISCHARGE AND GATE CHARACTERISTICS FOR 70,000-HP. TURBINE INSTALLATION

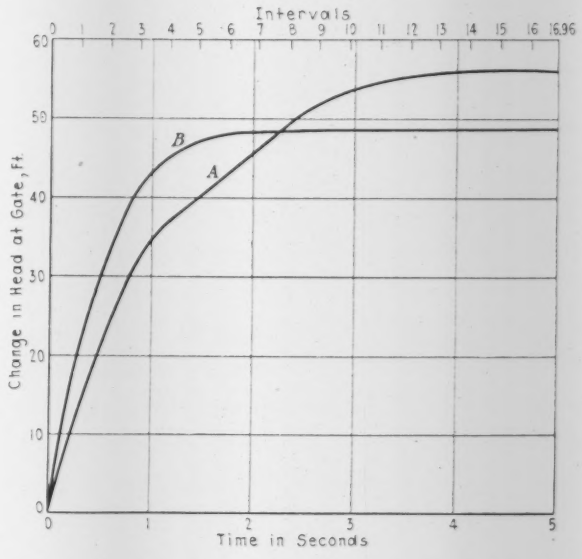


FIG. 2 WATER-HAMMER HEAD ON 70,000-HP. TURBINE PENSTOCK FOR FULL-LOAD REJECTION IN FIVE SECONDS

wheel unit would develop 40,000 hp.; however, it was capable of developing 44,000 hp. with a discharge of 200 c.f.s., which was the maximum capacity of the penstock.

The governors were tested and set to close the main needles from full opening in approximately $5^1/_5$ sec. The pressure regulators, designed to open when the needles were closed, were adjusted to close from full opening in 20 sec. During the test various loads from $^1/_4$ to full load were dropped, and the pressure and speed rises noted. With the full load of 32,000 kw. dropped, the following pressure characteristics were registered on the recording gages installed in the power house and at Anchor 8, which was located approximately in the middle distance and elevation of the line:

Gages in Power House

Maximum pressure rise, lb.	Percentage rise on static head	Maximum pressure drop, lb.†
100	9.9	65

Gages at Anchor 8

Maximum pressure rise, lb.	Percentage rise on static head*	Maximum pressure drop, in.
56	10.7	74

* Static head reduced to straight-line profile.
† Fifty-pound drop succeeded by rise in pressure.

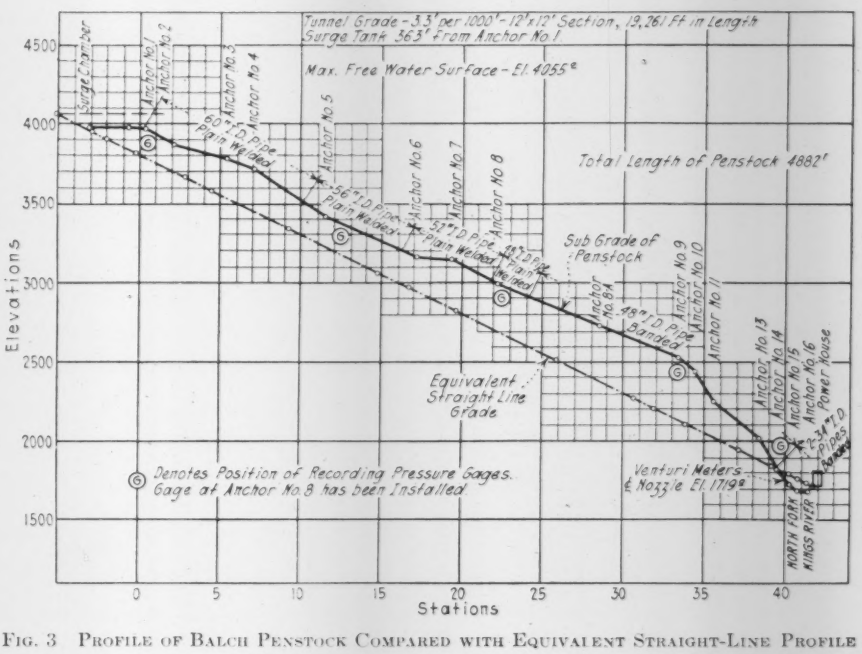

Tunnel Grade - 3.3' per 1000' - 12'x12' Section, 19,761 Ft. in Length
Surge Tank 363' From Anchor No. 1
Max. Free Water Surface - El. 4055
Total Length of Penstock 4882'
Sub Grade of Penstock
Equivalent Straight Line Grade
Denotes Position of Recording Pressure Gages. Gage at Anchor No. 8 has been Installed
Venturi Meters & Nozzle El. 1719
Elevations
Stations

FIG. 3 PROFILE OF BALCH PENSTOCK COMPARED WITH EQUIVALENT STRAIGHT-LINE PROFILE

The maximum rise at the power house for the above conditions as taken from Figs. 3 and 5 of Mr. Quick's paper, was 61 lb. The velocity of the wave of propagation based on the mean diameter and thickness of pipe was 3755 ft. per sec.

The maximum rise at the power house, computed by one of Allievi's formulas,

$$h = \frac{NH}{2} + H\sqrt{\frac{N^2}{4} + N}, \text{ where } N = \left(\frac{LV}{GTH}\right)^2 \text{ was 44 lb.}$$

A comparison of results, according to the writers, indicated the elastic-water-column theory to be more accurate than Allievi's formula quoted above. Practical limitations in the line under test, notably the branching pipes, variable diameters and thicknesses of pipe, venturi tubes, etc. probably accounted for the lack of agreement between recorded rises in pressure and the rises computed by the author's method, they believed. Moreover, they pointed out, it must be borne in mind that the pressure regulator opened at a faster rate than the needle closed, which caused an increased velocity in the pipe and an initial drop in pressure. Any or all of these factors, they indicated, might contribute to a higher rise in pressure than would take place in an ideal line.

The necessity for extensive experimentation under actual operating conditions seemed to them to be apparent. They agreed with the author that the use of approximate formulas should be discouraged and that the curves of the elastic theory should be used.

The writers did not lay claim to a deep study into the mathematics employed by the author, but felt that the terms H_0 and V_0 should be more clearly defined, especially for use under actual conditions in the field.

In his closure Mr. Quick wrote that the discussion disclosed considerable additional data of great practical value and assistance in actual studies of water-hammer problems. His paper had been confined in scope in an effort to place the various formulas on the

[18] Designing Engineer, San Joaquin Light and Power Corporation, Fresno, Cal.

[19] Asst. Designing Engineer, San Joaquin Light and Power Corporation, Fresno, Cal.

same plane; consequently the new data supplemented this to great advantage.

The new Hydroelectric Handbook by Creager and Justin, mentioned by Mr. Merrill, had not been published up to the time the Mr. Quick's paper had gone to press and thus unfortunately, had not been mentioned in the list of references. It added a wealth of information on water hammer, based upon the elastic-water-column theory, in a practical working form.

In determining the value of the pipeline constant K, Mr. Quick wrote that he used the net or effective steady head H_0 while Creager and Justin used the static head y, both measured from the gate to the point of relief. The use of H_0 was intentional since it first appeared in Equation [5] of the paper, being involved in the basic relation which determined the discharge from an orifice. Obviously, friction had to be deducted from the static head when determining the initial steady head when closure began.

The recovery of friction head during gate closure was not synchronous with the reduction in velocity at the gate and therefore could not be added directly to the pressure rise at the gate. However, analytical complications entered when the distribution of friction head along the conduit was taken into account so, in the absence of additional experimental data, it had been customary to consider the friction head as proportional to $(V)^2$. When introduced into Equation [5] in this manner, Equation [7] developed in a slightly different form, the variables ϕ and K being replaced by ϕ' and K', defined as follows:

$$\phi' = \frac{\phi}{\sqrt{1 - f(1 - \phi^2)}}, \quad K' = \frac{aV_0}{2gH_s}$$

where friction factor $f = \frac{H_s - H_0}{H_s}$, and H_s = static head (ft.).

The above modifications made K' and Rho identical, but imposed a modified gate closure which took into account the recovery of friction head in the manner above indicated. In all cases the velocity head in the conduit had not been included as its magnitude in practical cases was negligible.

N. R. Gibson[20] had demonstrated a method for separating the recovery of friction and velocity heads from a practical pressure rise-time curve. Possibly some reverse process could be developed to superimpose the recovered friction and velocity heads upon a calculated pressure rise-time curve.

As Mr. Harza had said, true theory and practice must agree; therefore the problem of friction was first in determining in just what manner it acted and then in combining it in this fashion into the general relation. Further experimental data were needed.

The extremely low values of a experienced in some wood-stave pipes, mentioned by Mr. Creager, would indicate the necessity for caution in establishing the safe minimum time of governor stroke. However, the value of pressure rise on instantaneous closure would be reduced in proportion, so the factors were compensating.

The range of accurate comparison and use of the Warren formula [10] could be established definitely by the methods used in developing Figs. 6 and 7. The experimental curves of Fig. 13 were based upon a non-uniform gate motion, which had the effect of reducing the maximum rise about 20 per cent below that which would occur with uniform closure, as could be checked readily from Fig. 3 or Fig. 5. Consequently, the agreement of Fig. 13 with Mr. Warren's formula might be altered materially under other gate closure and initial characteristics.

Mr. Warren's formula was based upon a gate-closure characteristic which, in the absence of reflected waves, caused the pressure to rise at a constant rate. This, we knew, meant uniform gate motion and therefore made Figs. 3 and 5 directly applicable for determining the maximum pressure rise without the tedious calculations required in using Equation [7] each time.

The step-by-step calculations of the N. R. Gibson method, mentioned by Mr. Strowger, gave the same results as Equation [7], being in fact based upon the same hypothesis, set up in a slightly different form. It was interesting that either method was applicable to studies of speed regulation where pressure rise occurred.

The Allievi formula used by Messrs. Jourdan and Reed was his simplified one based upon the rigid-water-column theory and therefore the same as Equations [14] and [15]. In such a high-head plant as Balch, K was much less than unity, making the results of Equation [15] too small as Fig. 6 showed. The simultaneous operation of a power needle nozzle and pressure regulator might not be exactly synchronous so that a complicated virtual gate motion could easily result and probably accounted in part for the differences noted. These people were to be congratulated for their interest in making water-hammer tests on such a large and striking plant and it was hoped that others might have the opportunity to extend such experiments.

In closing, Mr. Quick emphasized the importance of additional test data so that our knowledge of water hammer might be extended to include variable diameter, branch pipes, and friction.

Commenting on the subject matter of the papers by both Mr. Eck and Mr. Pfau, F. Nagler[21] wrote that he had found them intensely interesting, purely from a mathematical standpoint. The two analyses, he pointed out, brought the characteristic figure much more nearly under the designation "specific" than did the previously accepted definition of specific speed.

Practically, he said, there would be some hesitancy about changing the practice of using the formerly known specific speed defined in Marks' Mechanical Engineers' Handbook as characteristic speed. This practice, while not old in years, comprising as it did only the past 20 years or so, had dominated practically the entire period of water-wheel construction on a large scale, such construction having had its real growth during the twentieth century. Specific speed or characteristic speed had served wonderfully well even with the slight handicap of having to be expressed differently in the metric and English systems. In both systems, however, it had suffered from one definite drawback; it had been used generally to designate the characteristics of a turbine at full gate and best speed regardless of the efficiency obtained and neglecting entirely all considerations as to whether or not the power used for full gate was the maximum turbine capacity. Full gate on a turbine, he explained, was not a definite term nor was it even a definite characteristic of a turbine. It had frequently been remarked, he said, that position of full gate opening on a turbine was known only to the water-wheel builder, and he usually would not tell. He admitted the truth of this statement, and gave as the reason for the designer not telling the fact that usually he did not know or else was not willing to gamble on a phrase which in itself was ambiguous. Full gate, he explained, might be variously defined as follows:

1 The maximum opening to which the guide vanes could be moved as determined by mechanical stops.

2 That guide-vane opening beyond which any motion of the gates resulted in a decrease in the power. In other words, the guide-vane opening which gave the greatest output from the turbine and technically known as the over-gate point.

3 That guide-vane opening which resulted in the most power, short of the over-gate point, that still permitted of sensitive governor regulation.

Ideally, he said, the first and the third conditions should agree and it was the effort of the turbine designer to adopt an opening which conformed to the third requirement. It was not desirable to allow a turbine to operate strictly up to its over-gate point, because flattening out of the horsepower curve virtually precluded proper functioning of the governor which could regulate sensitively only if opening or closing of the guide vanes resulted definitely in an increase or decrease, respectively, of the horsepower. At the over-gate point the horsepower curve based on gate became flat and consequently the governor could not regulate.

Continuing, the writer explained that one of the difficulties in determining full gate opening arose from the fact that an over-gate point for the turbine itself was usually different from the over-gate point of the unit in the power-house setting; due to the fact that the effective head on the runner decreased as the guide vanes opened, and as a direct result of lowered head-race level, velocity-head losses, trash-rack losses, backing up of the tail level, etc., all such factors adding up in the direction of reducing the head. It had been the effort of the designer, particularly if responsible for governor regulation, to fix full-guide-vane opening at such a point

[20] Trans. A.S.M.E., vol. 45 (1923), p. 343.

[21] Engineer, Hydraulic Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

that the output curve based on gate opening for the entire unit in its power plant setting had a slight rising tendency at full gate. Because of the indeterminate effect of losses outside of the turbine structure, and also because of the fact that a guide-vane opening which was the over-gate point of a turbine for one head was not necessarily the over-gate point for the same turbine of another head, there had been a question as to what full gate actually meant.

This difficulty, he said, had been quite pronounced in its effect on the determination of specific speed, and by the same token the use of full load in determining specific speed was open to criticism. Actually, he pointed out, the most significant point for the determination of the characteristics of a turbine was the point of best efficiency. This was affected to a greater or lesser extent by the same factors that shifted full load or full gate one way or another, but it was less subject to variation than any other feature of a turbine. Some attempt had been made in the past to compare turbines by their specific speeds at their point of best efficiency, and he considered such practice decidedly commendable.

The analyses made by Messrs. Eck and Pfau were, in his opinion, a real contribution to this field of design, because, he explained, in taking into account the turbine efficiency they automatically differentiated between the ambiguous full gate and the more definite point of best efficiency by defining the former in terms of efficiency and basing the latter on a point which was measurable in similar terms.

The Gas Lift in Oil Fields

A SERIES of papers dealing directly or indirectly with this subject were presented at the meeting of the Petroleum Division of the American Institute of Mining and Metallurgical Engineers, October 19-20, 1927, at Fort Worth, Texas.

The fundamental conditions making it necessary to employ artificial pressure are given in a paper entitled, The Gas Factor as a Measure of Oil-Production Efficiency and the Variables Which Influence It, by Lester C. Uren.

Field studies and laboratory research have established the fact that the expulsive force which drives petroleum into wells from the reservoir sands in which it is stored by nature, is primarily an expression of the energy latent within compressed natural gas dissolved or occluded in, or otherwise associated with the oil. Each barrel of oil produced is forced into the recovery well by the expansive energy of a certain volume of compressed gas, originally stored with the oil in the pores of the reservoir rock; and each cubic foot of gas so produced with the oil and expanded to atmospheric pressure, reduces by so much the total natural energy available for oil expulsion. So important has this relationship between the volumes of gas and oil produced seemed, that petroleum-production technologists have come to regard the "gas-oil ratio," or the "gas factor" as it has been more conveniently termed, as a measure of oil-production efficiency. Different methods of oil recovery and production devices are now compared on this basis, and estimates of ultimate recovery obtainable through their use are considered by many to be inversely proportional to the values of their respective gas factors.

The solubility of gas in petroleum decreases in straight-line relationship with pressure. Accordingly as pressure is released within an oil-bearing formation by production of a part of the oil and gas, much of the remaining gas, though originally in solution in the oil, assumes gaseous form and exists within the oil in the form of minute bubbles. These occluded gas bubbles become trapped within the sand pores, and it is by reason of their continued expansion that oil is ejected. Experimental data indicate that the fluids move through the drainage channels in chains of alternating oil filaments and gas bubbles, the latter continually expanding due to decline in pressure as they approach the well outlets.

While expanding gas bubbles are thus largely responsible for the ejection of petroleum from the sands, it is also true that they interpose considerable resistance to flow. As each gas bubble passes from pore to pore of the reservoir sand through the restricted communicating channels, it must be subjected to considerable distortion, a requirement which in the aggregate occasions great energy loss. Furthermore, as the pressure declines and the occluded gas bubbles increase in size, the energy necessary to force them through the sand increases.

While the ultimate oil recovery will be increased through application of the proper degree of back pressure to producing oil wells, the time within which production is secured is ordinarily extended over a longer period than when no back pressure is used; and it will perhaps happen that the critical back pressure giving maximum ultimate oil recovery, will result in unduly prolonging the period of exploitation. Under the highly competitive organization of the present-day oil-producing industry, an operator may find it expedient, or more profitable, to accept a smaller total yield from his property in a short period of time than to extend operations over a longer period for a greater ultimate yield.

The gas factor which results in maximum ultimate oil yield will ordinarily not be the one which is productive of greatest ultimate profit to the producer. The oil conservationists and industrialists must therefore seek a middle ground between these two viewpoints in determining what constitutes a reasonable recovery efficiency that will be in accord with the public interest in a rapidly diminishing national resource, and yet fair to the producer from the economic standpoint. Price must control in the final analysis; higher price will compel more efficient recovery, while a depressed price structure will encourage production inefficiency.

The converse, namely, Effect of the Gas Lift on the Gas Factor and on the Ultimate Production of an Oil Well is discussed by E. O. Bennett, who comes to the following conclusions:

1 Where pressure conditions are suitable for using the gas lift the flow rate of wells thus producing can generally be increased over the rate which can be maintained by other means.

2 When the gas lift is used to increase the daily rate of a well, instead of being used as a means of back-pressure control, the ultimate production of a well will generally be decreased.

3 If the gas lift is used as a means of controlling the pressure on the formation the daily rate will be decreased but the well's ultimate production will be increased.

4 The gas lift is effective in increasing the ultimate production of a field under hydrostatic pressure where water has encroached into the oil-bearing formation.

5 Where offset wells are producing on the gas lift the best results and greatest ultimate recovery can be made when they are operated under similar conditions. An agreement as to pressure and rates should be reached by the operators. Trying to beat the offset generally works to the disadvantage of each.

6 To obtain the greatest ultimate yield from a well complete knowledge of pressures and volumes must be obtained. Proper equipment and supervision is the only way in which this can be done.

Mechanical installations for air-gas lift differ with the location. Those in the Gulf Coast area are described by L. L. Brundred in his paper Mechanical Installations for Air-Gas Lift in the Gulf Coast Area.

Expenditures of large sums for more or less permanent gas-lift equipment have been considered illogical. The average operator therefore considers quickness of installation, portability to a new field, and salvage value rather than cheapness of fuel and other costs of operation. The direct result of this attitude is that by far the bulk of all installations has been steam-driven compressors.

The coastal area is perhaps the most completely electrified oil-field section of the United States, in that high-tension power lines form a veritable network of connecting sources of electric power, at a very favorable rate to the consumer. Such a rate is surprising in view of the fact that all generating plants are steam driven. The availability of this relatively cheap power accounts for some of the recent installations of compressors belted to electric motors. The cost of operation is, however, hardly comparable with gas or oil engine-driven units.

The Influence of Elasticity on Gear-Tooth Loads

Progress Report No. 7 of the A.S.M.E. Special Research Committee on Strength of Gear Teeth[1]

THIS progress report is the fourth and last of a series of studies which have been necessary to analyze the results obtained on the Lewis gear-testing machine. In general they have been studies of the dynamics of elastic bodies, although they have been specifically directed to gear-tooth load conditions. All of these studies, however, are preliminary in nature and must be substantiated by the results of the actual tests before they can be accepted as substantially true. Undoubtedly many minor corrections at least—and possibly many major ones also—will have to be made before our hypothesis will be substantially complete and in reasonable agreement with the test data. For this reason the derivation of many of the equations which are to be used tentatively in the preliminary analysis have not been given in detail. Eventually, when the Committee feels that it is in a position to make a final report on any phase of its problem, it plans to give there the full derivation of any of the equations that the tests prove to be acceptable.

This present report deals with the influence of the rotating masses as affected by the elasticity of the shafts or other connections, and is specifically directed to the analysis of the mass conditions on the Lewis gear-testing machine. A series of tests to check these conditions was made by Messrs. Castellanos and Ortiz and reported in their thesis submitted in June, 1927, to the Massachusetts Institute of Technology.

IV INFLUENCE OF ROTATING MASSES

The effective mass at the pitch line of the test gears on the Lewis gear-testing machine, or of any other gears attached to shafts carrying other rotating masses, is variable. This variation will depend largely upon the speed of the gears and the diameter and length of the connecting shaft. This variation in the effective mass is caused by the elasticity of the connecting member. If the shaft were rigid and all the masses were rigidly connected to it, the effective mass would be constant, and all variations in velocity resulting from errors in the gear-tooth profiles would be imparted to all of the connected rotating bodies. The inertia of these bodies would thus cause a higher tooth load than that caused by the masses of the gear blanks alone, and the greater the mass of these connected bodies, the greater this additional tooth load would be.

However, the shafts or other connections are not rigid but are elastic, so that when it takes less load to twist the shaft than to accelerate the connected masses, the shaft will twist and the acceleration of the connected masses will be correspondingly reduced.

Under the conditions of test, the surfaces of the gear teeth of similar materials are moved apart practically the same distance when running at the same velocity regardless of the extent of the connected masses and of the extent of the error in the tooth profiles. This distance is the amount that is required to just break the electric circuit passing through the gear teeth, this break being recorded in the telephone receivers connected to this circuit. The distance the masses of the gear blanks themselves will move in relation to each other will not be identical because of the difference in the deformation of the tooth profiles under different loads. This difference may be so slight under the lighter loads, however, that we may be able to ignore it, at least in a study of the test results at the lower pitch-line velocities. At the higher speeds with the heavier test loads, this difference may be evident in the test results.

We have the following values involved in the Lewis gear-testing machine:

The effective weight of the test gear at its pitch line is about 32 lb. Its effective mass is therefore equal to about 1.00.

The effective weight of the test pinion and sleeve at its pitch line is about 16 lb. Its effective mass is about 0.50.

The effective weight of the 230-lb. flywheel which is attached directly to the pinion, at the pitch line of the pinion is about 1007 lb. Its effective mass is equal to about 31.25.

The effective weight of the 15-in. solid pulley on the pinion shaft at the pitch line of the pinion is about 620 lb. Its effective mass is equal to about 19.25.

The diameter of the pinion shaft is 3 in. Its length from the 15-in. solid pulley to the end of the pinion sleeve is about 9 in.

The torsional deflection of a solid cylindrical shaft is given by the following equation:

$$D = \frac{P}{F} \times \frac{32R^2L}{\pi d^4} \qquad [1]$$

where D = torsional deflection in inches at radius R
P = load in pounds at radius R
R = radius in inches where load is applied
L = length of shaft in inches
d = diameter of shaft in inches, and
F = torsional modulus of elasticity.

In this case
$R = 3.000$
$L = 9.000$
$d = 3.000$
$F = 12{,}600{,}000$

whence

$$D = \frac{P}{1{,}237{,}000} = 0.0000008084\ P.$$

We shall now attempt to determine the influence of the elasticity of the shaft on the amount of the acceleration load of the solid pulley that will be effective at the pitch line of the test pinion. Thus when

f_1 = force required to accelerate the solid pulley
f_2 = force required to twist shaft
f_r = resultant force required to accomplish a combined acceleration of the solid pulley and twisting of the connecting shaft,

then

$$f_r = \frac{f_1 \times f_2}{f_1 + f_2} \qquad [2]$$

We shall now direct our attention to f_1 or the force required to accelerate the solid pulley. When

e'' = additional distance in inches to be moved
d = distance in inches in which acceleration takes place
m_a = effective mass of solid pulley, and
V = pitch-line velocity of test gears in feet per minute and also velocity of effective mass.

Then from Equation [16], Section I,[2] we have

$$f_1 = \frac{m_a e'' V^2}{150\ d^2} \qquad [3]$$

The analysis of the meshing conditions of gears given in Progress

---

[1] The personnel of the A.S.M.E. Special Research Committee on the Strength of Gear Teeth is as follows:
Wilfred Lewis, *Chairman*, President, Tabor Manufacturing Company, 6225 Tacony Street, Philadelphia, Pa.
Carl G. Barth, 420 Whitney Avenue, New Haven, Conn.
Earle Buckingham, Professor, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
Ralph E. Flanders, Manager, Jones & Lamson Machine Company, Springfield, Vt.
Arthur M. Greene, Jr., Dean, School of Engineering, Princeton University, Princeton, N. J.
Clarence W. Ham, Professor of Machine Design, University of Illinois, 115 Transportation Building, Urbana, Ill.
Charles H. Logue, *Secretary*, Consulting Engineer, 123 Clarke Street, Syracuse, N. Y.
Fred E. McMullen, Manager Cutter Department, The Gleason Works, Rochester, N. Y.
Edward W. Miller, Chief Engineer, Fellows Gear Shaper Company, Springfield, Vt.
Ernest Wildhaber, 379 Alexander Street, Rochester, N. Y.

[2] See MECHANICAL ENGINEERING, June, 1927, p. 646.

Report No. 5[3] points out the possibility that the relationship (e''/d^2) may be practically a constant regardless of the extent of the error. The following approximation for such a condition is given in that report:

$$\frac{e''}{d^2} = 0.375\,p\left(\frac{R_1 + R_2}{R_1 \times R_2}\right)^2 \quad [4]$$

where p = circular pitch of gears in inches
R_1 = pitch radius of test pinion in inches, and
R_2 = pitch radius of test gear in inches.

Substituting this value in Equation [3], we have

$$f_1 = 0.0025\,p\left(\frac{R_1 + R_2}{R_1 \times R_2}\right)^2 m_a V^2 \quad [5]$$

Under the specific conditions of these tests,

$$p = 1.0472$$
$$R_1 = 3.0000$$
$$R_2 = 8.0000$$

whence

$$f_1 = 0.00055\,m_a V^2 \quad [6]$$

We shall now direct our attention to the force required to twist the shaft an amount equal to e'' at a radius of R_1. Thus when

z = elasticity factor of shaft
F = torsional modulus of elasticity
D = deflection in inches at radius R_1 (Equation [1]), and
P = load in pounds at radius R_1,

$$z = \frac{DP}{F} \quad [7]$$

Under the specific conditions of these tests,

$$z = 0.098175 \quad [8]$$

Then

$$e'' = \frac{f_2}{zF}$$

whence

$$f_2 = e''zF \quad [9]$$

The percentage of the mass of the solid pulley which will be effective at the pitch line of the test gears would then be equal to f_2/f_1. Thus when

m_a = effective mass of solid pulley, and
m_b = mass effect of solid pulley at pitch line of test pinion,

$$\frac{m_b}{m_a} = \frac{f_2}{f_1} \quad [10]$$

Substituting the value of f_2 from Equation [2], we have

$$\frac{m_a}{m_b} = \frac{f_2}{f_1 + f_2} \quad [11]$$

We must now direct our attention to the distance which the test pinion moves in relation to the gear because of the error in the tooth profile. This distance will depend upon the extent of the effective profile error and the relative masses of the mating gears at the pitch line. Thus when

m_1 = effective mass acting at pitch line or pinion
m_2 = effective mass acting at pitch line of gear
e' = effective error in tooth profile, and
e'' = relative movement of test pinion,

then

$$e'' = \frac{m_2 e'}{m_1 + m_2} \quad [12]$$

The value of m_1 is the sum of the effective mass of the pinion itself, which will be a constant, and the mass effect, m_b, of the solid pulley, which is a variable. In addition there will be about one-half the mass of the connecting shaft itself which is effective at the pitch line of the pinion as well as the mass effect of other rotating parts attached to the shaft. These additional mass increments will be so small that they will be ignored in this analysis. Similar small mass effects on the gear shaft will also be ignored. Thus when

m_p = effective mass of pinion blank itself at pitch line,

$$m_1 = m_b + m_p \quad [13]$$

Substituting this value into Equation [12], we have

$$e'' = \frac{m_2 e'}{m_b + m_p + m_2} \quad [14]$$

In this equation we have two unknown values, m_b and e''. We shall therefore substitute the value of f_1 from Equation [6] and the value of f_2 from Equation [9] in Equation [11] and solve for e''. This gives us

$$e'' = \frac{0.00055 m_a m_b V^2}{zF(m_a - m_b)} \quad [15]$$

Equation [15] also has the two same unknown values as Equation [14]. By equating these two values of e'' and solving for m_b, we obtain

$$(0.00055\,m_a V^2)m_b^2 + [(0.00055\,m_a V^2)(m_p + m_2) + zFe'm_2]\,m_b - zFe'm_a m_2 = 0 \quad [16]$$

The solution of Equation [16] for m_b would give us a very complex formula. For simplicity in handling we shall therefore let

$$A = 0.00055\,m_a V^2$$
$$B = (0.00055\,m_a V^2)(m_p + m_2) + zFe'm_2$$
$$C = zFe'm_a m_2$$

whence

$$m_b = \frac{\sqrt{B^2 + 4AC} - B}{2A} \quad [17]$$

(Under the specific conditions of these tests, $zF = 1{,}237{,}000$.)

We shall now consider the effective mass influence at the pitch line of the test gears. Thus when

m = effective mass influence at pitch line of test gears
m_1 = effective mass at pitch line of pinion, and
m_2 = effective mass at pitch line of gear,

$$m = \frac{m_1 \times m_2}{m_1 + m_2} \quad [18]$$

We shall now introduce the specific values involved in Run E without the flywheel attached directly to the pinion. These gears are hardened and ground steel gears with an error of about 0.0005 in. For this example we have the following values:

e = 0.005 (actual profile error)
m_a = 19.25
m_2 = 1.00
m_p = 0.50

We have from Equation [4], Section II,[4]

$$e' = e - \frac{d_t}{2} \quad [19]$$

And from Equation [2], Section II,

$$d_t = P\frac{E_1 z_1 + E_2 z_2}{E_1 z_1 \times E_2 z_2} \quad [20]$$

In this case E_1 and E_2 = 30,000,000, and z_1 and z_2 = 0.10582, whence

$$d_t = 0.00000063P$$

and

$$e' = e - 0.000000315 \quad [21]$$

where P = applied load in pounds.

In Fig. 1 is shown a graph of Run E. From this graph, which represents the average test loads, we get the loads given in

[3] See MECHANICAL ENGINEERING, July, 1927, p. 767.

[4] See MECHANICAL ENGINEERING, July, 1927, p. 768.

Table 1. Corresponding values of e' as determined from Equation [21] are also given in Table 1. Values of m_b as determined

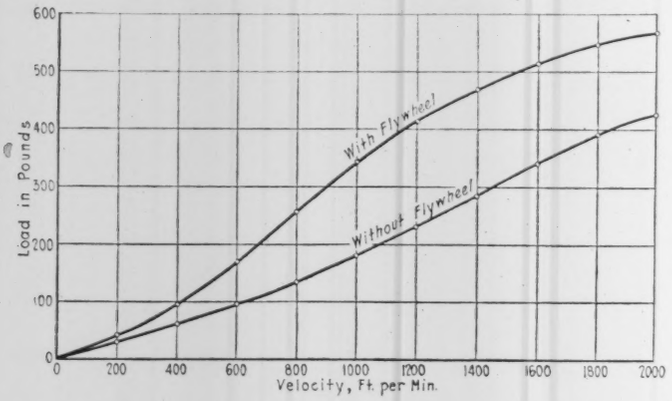


FIG. 1 GRAPH OF RUN E

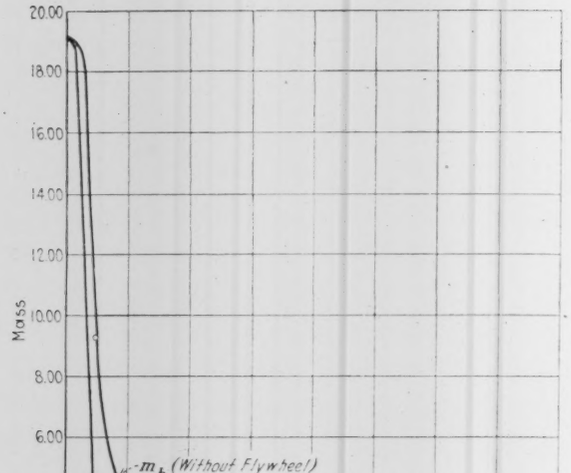


FIG. 2 VALUES OF m_b WITH AND WITHOUT FLYWHEEL DIRECTLY ATTACHED TO PINION

from Equations [16] and [17], together with values of m as determined from Equation [18], are also included in this table.

For Run E, with the flywheel attached directly to the pinion, we have the same values as before except that $m_p = 31.75$.

Proceeding as before, we obtain the values given in Table 2. In Fig. 2 are plotted the values of m_b with and without the flywheel attached directly to the pinion. It will be noted that the influence of the mass of the solid pulley at the pitch line of the pinion reduces very rapidly as the speed is increased. When the flywheel is attached to the pinion, this increased mass reduces the amount of movement of the pinion, which in turn makes the effective mass of the other rotating parts attached to the pinion shaft reduce even more rapidly than before. This same result should be obtained when the extent of the error on the gear-tooth profiles is reduced.

In Fig. 3 are plotted the values of m with and without the flywheel attached to the pinion. It will be noted that the value of m with the flywheel attached directly to the pinion is almost a constant and very nearly equal to the effective mass of the test gear.

Assuming that the amounts of movement of the masses of the gear blanks are the same with and without the flywheel attached directly to the pinion when the gears are running at any given pitch-line velocity, then the test loads would be directly proportional to the effective masses. As noted before, this assumption is an approximation which is not strictly true. The error in this approximation should be small at the lower pitch-line speeds and increase as the speeds increase.

TABLE 1

Pitch-line velocity V	Test load P	Effective error e'	m_b	m
100	14	0.000496	7.526	0.889
200	29	0.000491	3.989	0.818
300	44	0.000486	2.578	0.755
400	60	0.000481	1.834	0.700
500	77	0.000476	1.380	0.653
600	95	0.000470	1.076	0.612
700	114	0.000464	0.861	0.576
800	135	0.000457	0.702	0.546
900	157	0.000451	0.583	0.520
1000	180	0.000443	0.488	0.497
1100	204	0.000436	0.414	0.477
1200	230	0.000428	0.354	0.461
1300	257	0.000419	0.304	0.446
1400	285	0.000410	0.263	0.433
1500	312	0.000402	0.229	0.422
1600	340	0.000393	0.201	0.412
1700	366	0.000385	0.177	0.404
1800	390	0.000377	0.156	0.396
1900	412	0.000370	0.139	0.390
2000	425	0.000366	0.126	0.385

TABLE 2

Pitch-line velocity V	Test load P	Effective error e'	m_b	m
100	20	0.000494	2.697	0.972
200	40	0.000487	0.783	0.970
300	64	0.000480	0.355	0.970
400	94	0.000470	0.198	0.970
500	130	0.000459	0.125	0.970
600	170	0.000446	0.084	0.970
700	212	0.000433	0.060	0.970
800	257	0.000419	0.045	0.970
900	302	0.000405	0.034	0.970
1000	343	0.000392	0.027	0.970
1100	380	0.000380	0.022	0.970
1200	414	0.000370	0.018	0.970
1300	442	0.000361	0.015	0.970
1400	469	0.000352	0.012	0.970
1500	493	0.000345	0.0105	0.970
1600	514	0.000338	0.0091	0.970
1700	531	0.000333	0.0079	0.970
1800	546	0.000328	0.0069	0.970
1900	558	0.000324	0.0062	0.970
2000	567	0.000321	0.0055	0.970

In Table 3 are given the values of the test loads without the flywheel attached to the pinion, divided by the test loads with

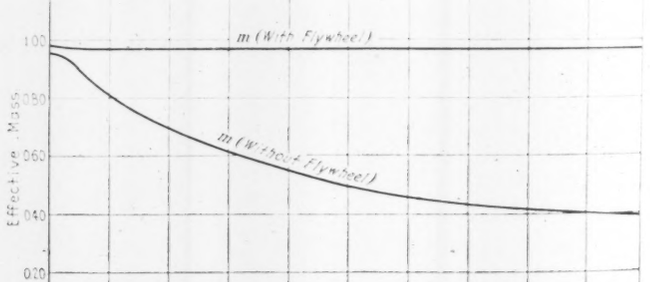


FIG. 3 VALUES OF m WITH AND WITHOUT FLYWHEEL ATTACHED TO PINION

the flywheel attached to the pinion. For comparison, the calculated values for m without the flywheel divided by the calculated values of m with the flywheel are also given in Table 3. These values are also plotted in Fig. 4.

It will be noted that the two curves in Fig. 4 show a certain amount of similarity for pitch-line velocities up to about 600 ft. per min., but that beyond that speed they show marked differences. It is probable that the major cause of the difference is the fact that the flywheel is not rigidly attached to the pinion, and that at the higher speeds the movement of the mass of this flywheel is not identical with that of the test pinion. For example, the flywheel is made in two parts and bolted together. After the first runs with the flywheel bolted together and bolted to the pinion disk to which the test pinion is also fastened, evidence of relative motion of these parts in relation to each other was apparent. The fly-

wheel was then doweled to the pinion disk and also the two halves of the flywheel were doweled together, and it then required appreciably greater test loads at the higher speeds to maintain the

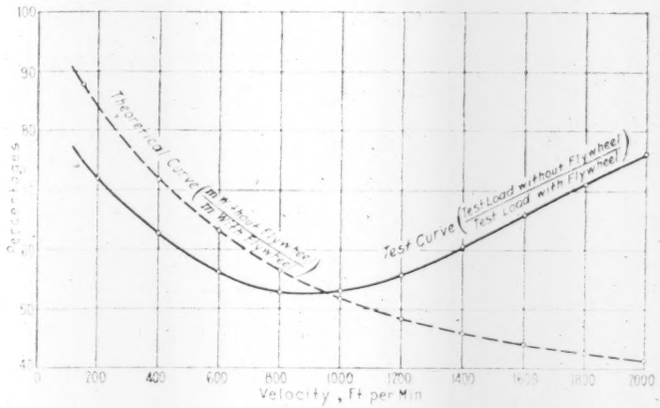

Theoretical Curve (m without Flywheel / m with Flywheel)
Test Curve (Test Load without Flywheel / Test Load with Flywheel)
Velocity, Ft per Min

FIG. 4 CALCULATED VALUES FOR m WITHOUT FLYWHEEL DIVIDED BY CALCULATED VALUES FOR m WITH FLYWHEEL

electrical circuit. It is possible that some slippage factor should be introduced into the calculations for the effective mass when the flywheel is employed.

It is also possible that the critical speed which exists when these gears are running at about 600 ft. per min. pitch-line velocity is another contributing factor. In addition, the assumptions on which this comparison is based are not strictly true, and part of the discrepancy is probably due to the influence of greater deformations of the gear teeth at the higher loads and speeds.

TABLE 3

Pitch-line velocity V	$\frac{P \text{ without flywheel}}{P \text{ with flywheel}}$	$\frac{m \text{ without flywheel}}{m \text{ with flywheel}}$
100	0.700	0.915
200	0.725	0.843
300	0.687	0.778
400	0.638	0.722
500	0.592	0.673
600	0.559	0.631
700	0.538	0.594
800	0.525	0.563
900	0.520	0.536
1000	0.525	0.512
1100	0.537	0.492
1200	0.556	0.475
1300	0.581	0.460
1400	0.608	0.446
1500	0.633	0.435
1600	0.661	0.425
1700	0.689	0.416
1800	0.714	0.408
1900	0.738	0.402
2000	0.750	0.397

For purposes of further analyses of the test runs, however, we shall use values for the effective masses calculated by the several equations given in this study. The next step in this analysis will be the examination in detail of all of the test runs with hardened and ground steel gears, which comprise Runs A to H, inclusive.

Tooth Pressures for High-Speed Gears

ALLOWABLE tooth pressures for high-speed gears is mostly a matter of experience. In the field of low-speed work involving velocities up to 4000 ft. per min., there is a wide range of experience on which many valuable data have been based, and in this field the load-carrying capacities of gears can be said to be fairly well established. With velocities above 4000 ft. per min., the available data are limited to the experience of the comparatively few manufacturers specializing in high-speed applications. Based upon his individual experience, each manufacturer has attempted to develop formulas from which allowable tooth pressures can be figured.

The company with which the writer is associated has confined its herringbone gear work exclusively to high-speed applications — turbine-driven generator sets, turbine-driven pumps, geared marine sets, and speed-increasing gears for turbine- and motor-driven centrifugal compressors. Typical tooth pressures taken from these applications have been used as a basis in developing formulas.

Using 0.40 to 0.50 heat-treated carbon steel, an allowable static stress of 12,500 lb. per sq. in. is used. Considering that this stress is localized near the root of the tooth, a formula based upon the tooth shape for 1 diametral pitch has been developed, which will give the allowable static pressure per inch of face at the pitch line. This formula contains a value known as the tooth shape factor, the same as the well-known Lewis formula. This factor Y is based on the formula for a cantilever beam loaded at the end, and is as follows:

$$Y = \frac{N^2 R_1}{6MR}$$

where N = thickness of tooth at plane of maximum stress
M = distance from the point where the line of applied load intersects the center line of the tooth, to the plane of maximum stress;
R_1 = radius from center of pinion to intersection of center line with line of applied load; and
R = radius of pitch circle.

R and R_1 are introduced to bring the pressure to the pitch line. The values of Y for various numbers of pinion teeth are given in Table 1 of the original article.

The following formula has been developed for high-speed work, 4000 ft. per minute and more.

$$K = \frac{78}{78 + \sqrt{V}}, \text{ where } K = \text{velocity factor.}$$

In applying this formula, it will be found that K varies from about 0.55 to 0.40 for pitch-line velocities ranging from 4000 to 12,000 ft. per min. Experience has shown that for satisfactory operation at a pitch-line velocity of 4000 ft. per min., gears must be cut as accurately as is commercially possible, and if this is done, the increase in velocity will have little effect on the allowable tooth pressure until a speed is reached at which the centrifugal force may render it difficult to retain an adequate oil film on the teeth. The velocity at which this condition may occur is not definitely known, but we have run gears as high as 14,000 ft. per min. without any ill effects being apparent, or any evidence of lack of lubrication. Inserting the factor K in the formula we now have:

$$L = SYK$$

The preceding formula for L gives the allowable tooth pressure on a tooth of 1 diametral pitch for a given velocity and a given number of teeth in the pinion. There remains, then, the factor for the size of the tooth, or in other words, the diametral pitch.

The average allowable loads per inch of face for a 31-tooth pinion having a speed of 7500 ft. per min. are, in accordance with actual service operation, as follows:

4 D.P.	475 lb.	10 D.P.	250 lb.
5 D.P.	400 lb.	12 D.P.	200 lb.
6 D.P.	350 lb.	14 D.P.	175 lb.
8 D.P.	300 lb.	16 D.P.	150 lb.

In solving for the diametral-pitch factor from the loads just given, we find that for a 10-pitch tooth, the factor would be equal to 10.

Also that, dividing by the diametral pitch for 12, 14, and 16 pitches, we find the resulting loads varying only slightly from those agreeing with actual service. Hence this diametral-pitch factor, or P-factor as it is termed, may for practical purposes be the same as the diametral pitch for 10-, 12-, 14-, and 16-pitch teeth. For larger teeth, factor P is increased as the size of the tooth increases thereby reducing slightly the allowable load over what would be obtained if the diametral pitch were used. Factors P for various diametral pitches are given in Table 2 of the original article.

(Based on a paper read before the American Gear Manufacturers' Association by A. A. Ross, engineer, General Electric Co., Lynn, Mass. *Machinery*, vol. 34, no. 2, October, 1927, p. 110.)

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Modern Conceptions Concerning Ignition and Combustion Processes in Diesel Engines

IT IS RATHER remarkable, the author considers, that while Diesel engines have been operated for nearly thirty years it is only quite lately that true light has been shed on the character of the factors governing the ignition and combustion of the fuels used. The original view concerning the former was that it was gasification of the fuel that made ignition possible, and Dr. Rudolph Diesel himself held decidedly to this view.

Back in 1907 P. Rieppel, while looking for a reasonable explanation of the difference in the behavior in a Diesel engine of aliphatic gas oils and aromatic coal tars pointed out that the more suitable oils formed an oil gas even with comparatively small additions of heat, while the less suitable ones required a larger supply of heat over a long time to become ignited. Rieppel ascribed this to the dominating influence of the so-called hydrogen number of the fuel. (Number expressing the molecular ratio of hydrogen to carbon.) He attached some importance to it because of the fact that in oils suitable for use in Diesel engines hydrogen apparently separates on the supply of comparatively small amounts of heat, and because of its (presumably) low ignition point initiates the ignition of the other molecules.

Other investigators accepted his views, with the result that the opinion came to be generally held that ignition in the combustion chamber of a Diesel engine was necessarily preceded by conversion of the fuel into an oil gas. The author considers it remarkable that no one raised the question as to how such a complete gasification of the fuel could take place in the extremely short space of time between injection of the fuel and its ignition, a space of time which, as a rule, does not exceed a few thousandths of a second.

It was only the work of Wollers and Ehmcke (suggested to them by the late Dr. Alt) that laid the foundation for a conception of combustion seemingly in agreement with modern views and facts. Briefly, they produced apparently convincing evidence against the possibility of gasification in the Diesel engine, and subsequent facts obtained by observation on running engines support their conclusions.

Wollers and Ehmcke investigated four fuel oils notable for the difference of their behavior in a Diesel engine, namely, a light oil made from primary tar, a paraffin oil, a vertical-oven tar, and a coal tar. They investigated these fuels by means of an electrically heated bomb and analyzed the gas mixtures produced at four different pressures. It was found that the functional relation between vapor pressure and temperature on one hand and duration of gasification on the other, did not differ in the various oils as much as one might have expected from their behavior when used as engine fuels. In Fig. 1, for example, the curve of the paraffin oil—known to be easy burning—coincides fairly well with the curve of the vertical-oven tar, which is quite difficult to burn, but lies in between the curves for the light oil made of primary tar and generally unsuitable for use in Diesel engines on one hand and coal-tar oil on the other. Fig. 2 is likewise disturbing in that the curve for the paraffin oil well suited for use in Diesel engines lies between the light oil from primary tar, far less suitable for this purpose, and the coal-tar oil.

In another series of tests made by the same investigators the oil vapors formed in the bomb were condensed by sudden cooling of the vessel and the relative volume contents of the oil vapors and oil gases were determined by measurement of the partial pressures of the residual oil gases. The results are given in the original article in the form of a table, from which it appears that here again the situation did not agree at all with the previously current view that ignition had to be preceded by gasification of the fuel. As a matter of fact, with the same prevailing pressures, the fuels unsuitable for use in the Diesel engine, namely, the coal-tar oil and the vertical-oven tar, gave off a much larger amount of gas than the aliphatic paraffin oil, and it was only in the case of the aromatic oil made from primary tar that the gaseous portion of the vapor-gas mixture in the bomb was comparatively small. Of interest is also the fact disclosed by the gas analysis that in the case of the aromatic coal-tar oil the output of hydrogen was sufficiently large, while the aliphatic paraffin oil was quite backward in this respect. This is exactly opposite to what was generally believed to be the case in so far as behavior of fuels in the Diesel engine was supposed to be. Still more convincing evidence as to the unreliability of previously prevailing views was given by results of ignition tests, first made on the oil gases obtained from the four fuels tested, and then on the fuels themselves in liquid state. The ignition points of the oil gases were determined in the Dixon furnace and the ignition points of the liquid oils in a Moore ignition tester, both series of determinations being carried out in a stream of oxygen at 1 atmos. pressure. The data obtained are given in Table 1. The startling fact disclosed by these tests was that the ignition point of the gases was found to be very much higher than that of the liquid ungasified fuels; furthermore, the ignition points of the oil gases generated in the bomb from the various oils were found to be very nearly alike and gave no indication as to the variable behavior which the oils show in Diesel engines. Contrariwise, the ignition points of the liquid oils themselves when arranged in an ascending scale, follow each other exactly in the order of their degree of combustibility in the Diesel engine itself. (Table 1.)

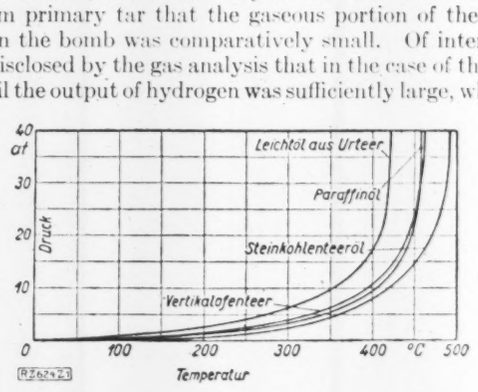


FIG. 1 PRESSURE-TEMPERATURE CURVES OF VARIOUS FUEL OILS ACCORDING TO WOLLERS AND EHMCKE

(*Leichtöl aus Urteer* = light oil from primary tar; *Steinkohlenteeröl* = coal-tar oil; *Vertikalofenteer* = vertical-oven tar; *druck* = pressure.)

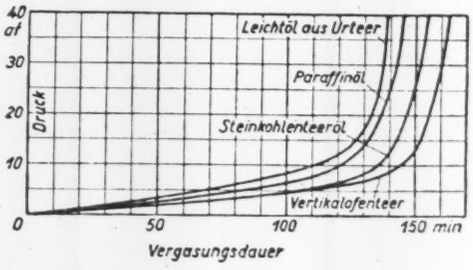


FIG. 2 PRESSURE-TIME DIAGRAMS OF FUEL OILS ACCORDING TO WOLLERS AND EHMCKE

(*Leichtöl aus Urteer* = light oil from primary tar; *steinkohlenteeröl* = coal-tar oil; *Vertikalofenteer* = vertical-oven tar; *druck* = pressure; *vergasungsdauer* = duration of vaporization.)

nearly the same, is explained on the basis of the gas analysis carried out by Wollers and Ehmcke by the simple fact that the oil-gas mixtures have all the same constituents and very nearly in their relative proportions. It is therefore extremely unlikely that the ignition of the easily ignitible liquid fuel oils occurs through the intermediary of the much less easily ignitible oil gases.

MEASUREMENT OF IGNITION TEMPERATURES IN THE ENGINE

A further proof that no vaporization of the fuel oil can take place in the combustion chamber of an oil engine is given by measurement of ignition temperatures in the hot-bulb engine, where the

TABLE 1 IGNITION POINTS OF OIL GASES AND LIQUID FUEL OILS ACCORDING TO WOLLERS AND EHMCKE

	Ignition points in an oxygen stream at 1 atmos.	
	Oil gases	Liquid fuel oils
Paraffin oil	614 to 655	240
Light oil from primary tar	615 to 651	326
Coal-tar oil	645	415
Vertical oven tar	635 to 661	468

ignition must naturally occur in the same way as in the Diesel engine. The hot-bulb engine is particularly suitable for an investigation of this kind, because the wall temperature of one part of the

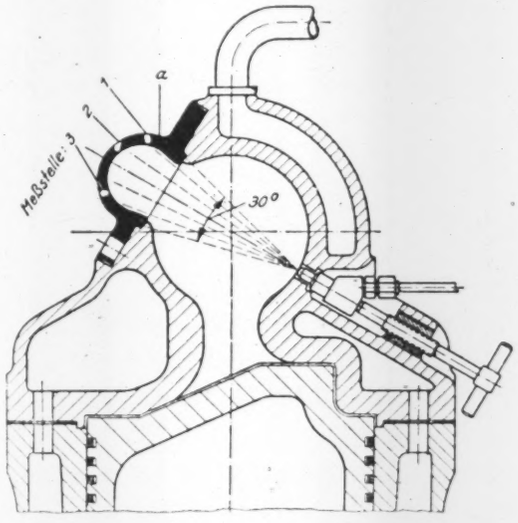


FIG. 3 METHOD OF TEMPERATURE MEASUREMENT ON HOT BULB OF AN A.E.G. MEDIUM-PRESSURE MOTOR OF 30 HP. PER CYLINDER OUTPUT
(*a* = hot bulb; *messstelle* = place at which temperature is measured.)

combustion chamber, to wit, the hot bulb, is directly accessible for purposes of measurement. In this case measurements were carried out on an A.E.G. medium-pressure engine of a new kind having an output of 30 hp. per cylinder at a compression pressure of 15 to 16 atmos. and ignition by means of a hot bulb *a* (Fig. 3) preheated from the outside for starting. The precision of the measurements (method described in the original article) is said to have been ± 1 per cent. The lowest temperature of the hot bulb was found at three-quarters load and was of the order of 270 to 315 deg. cent., which means that it was more than 100 deg. cent. below the ignition point of acetylene, this latter being selected because according to a table in the original article it has the lowest ignition temperature of all the constituents in oil-gas mixtures. Had it been absolutely necessary to have gasification of the fuel precede ignition, no ignition whatever could have taken place in this motor from full load down to one-quarter load, as within this range of loads the temperature of the igniting device lies below the lowest temperature of ignition of any of the constituents of the oil-gas mixture. As a matter of fact, however, uniform and certain ignition is obtained in this motor at all loads.

VAPORIZATION AS A CONDITION OF IGNITION

Considerable light has been thrown lately on another controversial subject, namely, whether or not vaporization of the injected fuel must precede ignition. Alt has already pointed out that the average boiling points of many difficultly ignitible aromatic fuel oils are actually lower than the corresponding temperatures of gas oil and paraffin oil, and that furthermore the average boiling points of aliphatic fuel oils are above their supposed ignition temperatures. Alt's conclusion is that vaporization is of no particular importance for ignition. Quite recently Neumann subjected the vaporization process to a mathematical analysis which showed that because of lack of time there can be no material vaporization of the fuel-oil droplet preceding the ignition. This is shown by graphs in the original article. The time actually available for vaporization is the period between the beginning of injection and the beginning of combustion, which is even shorter than assumed by Neumann. What is more, a substantial part of this time, as a rule more than one-half, is consumed by the "injection lag" and comprises the period between the beginning of the operation of the fuel pump and the beginning of the actual injection. This time is employed for submitting the oil to the pressure and for the expansion of the oil piping. According to measurements carried out by the author himself, the ignition process proper consumes from $^1/_{300}$ to $^1/_{400}$ sec., certainly not more than $^1/_{100}$ sec., and in this short time, according to a curve in the original article, the volume of the oil droplet can decrease by barely 0.1 per cent. which means that practically no vaporization of the injected oil takes place previous to ignition.

THE HYDROGEN NUMBER

A table in the original article gives analyses and characteristic numbers of six aliphatic fuel oils investigated in the chemical laboratories of the A.E.G. Turbine Works. These are a German paraffin oil, a North American gas oil, two Mexican, one Argentinian, and one South African gas oil. This analysis has shown that one of the Mexican oils and the South African oil have very low hydrogen numbers and yet are quite suitable for Diesel-engine work and have good heating values. These and other data would indicate that hydrogen does not play the important part in initiating ignition that was formerly ascribed to it, particularly in view of its very high ignition point (580 to 590 deg. cent.).

If now neither gasification nor vaporization of the fuel oil is necessary for ignition, it would appear that the droplets must ignite directly in their liquid state after a previous preheating to a certain temperature which constitutes the ignition point, this latter being the lowest temperature at which the body will self-ignite. This temperature has been determined by means of a modified Moore ignition-point indicator, and the measurements can be carried out either in air or in oxygen at 1 atmos. pressure. A more correct way is, however, to determine the ignition point in air at the same pressure as obtains in a Diesel engine at the end of the compression period, and this is exactly what Tausz and Schulte have done.

According to Table 2, which is based on their work, entirely different values for ignition temperatures have been obtained with the different oils. As a rule the ignition temperature in oxygen is

TABLE 2 IGNITION POINTS OF CERTAIN ALIPHATIC FUELS IN AIR AND OXYGEN AT 1 ATMOS. PRESSURE AND IN COMPRESSED AIR ACCORDING TO TAUSZ AND SCHULTE

	Ignition points at 1 atmos.		Ignition points in compressed Air	
	In air	In oxygen	Deg. cent.	Atmos. pressure
Gas oil	336	270	205	27
Petroleum	290 to 435	250 to 265	200	26
Shale oil	354 to 435	272 to 290	200	23
Paraffin	388 to 414	243 to 258	228	11.5

lower than that in air, and is still lower in air compressed to the pressure employed in Diesel engines, although with some materials such as ethylbenzol, allyl-alcohol, and trinitro-phenol, the ignition point in oxygen is higher than in air. These observations provide the basis for an interesting explanation of the mechanism of ignition.

According to this a layer of oxygen is formed on the oil previous to ignition, leading to the creation of superoxides (peroxides, moloxides, etc.). Compounds supersaturated in oxygen are stable only within a narrow and easily exceeded range of pressure and temperature; beyond this range these compounds suddenly break up, and in doing so evolve heat in sufficient quantity to ignite the material under consideration.

In the case of fuels whose ignition point in oxygen is higher than in air, the superoxide can take up further oxygen before it breaks up (hence, before ignition takes place). It would appear that the formation of an oxygen layer need affect only a comparatively

small share of the molecules composing the droplet of fuel, as the heat liberated at the break-up of the superoxides is sufficient to disintegrate the remaining molecules of the droplets of fuel and thereby initiate combustion therein. Hence it is only in so far as this formation of oxygen compounds represents a decomposition of the fuel—which, as stated, takes place to only insignificant extent—that one may say that the injected fuel oil decomposes previous to ignition.

IGNITION IN COMPRESSED AIR—IGNITION LAG

The work of Tausz and Schulte has shown that as the air pressure increases, the ignition point, depending on the material, may be either lowered or raised. Mixtures do not behave in the same manner as their original components, and the original article gives data as to this behavior of a number of materials. Neumann was of the opinion that it is more correct to explain the lowering of the ignition point by increased air density rather than by increased air pressure, since the droplet of oil is heated by heat conduction, which is a function of air density. By plotting the ignition temperatures found by Tausz and Schulte against the air density γ Neumann found a curve of absolute ignition temperatures T_z, giving the law $T_z = C\ \gamma^{-m}$. For aliphatic fuels C is about 709 and m is 0.160. In the opinion of the author, Neumann is correct in asserting that air density and not air pressure determines the location of the ignition point. The Neumann formula is not suitable for practical purposes in dealing with the average ignition points of various fuels, since these show great differences which must be taken into consideration in the selection of the degree of compression, and yet do not appear in the above formula.

Gas oil, which is the fuel practically exclusively used in Diesel engines, ignites according to Tausz and Schulte under ordinary engine compression at about 200 deg. cent. It is therefore at least to this temperature that one must heat the oil droplets introduced into the combustion chamber by air or solid injection. In the case of compressorless motors, compressions of 27 to 28 atmos. are employed in starting the motor from cold, while in air-injection motors as high as 30 atmos. may be required, because of the cooling effect of the expanding air-injection blast. If one takes 28 atmos. as the right compression it will be found from the Schüle gas-entropy diagram that with a cold-engine starting temperature of 27 deg. cent., the proper end temperature will be 500 deg. cent., while with a warm-engine starting temperature of 50 deg. cent. the proper end temperature will be 550 deg., which means an excess of temperature over the ignition point of from 300 to 350 deg. cent. This is shown in Fig. 4.

The intersections of the curve of ignition point for gas oil with the curve of compression pressure for 27 and 50 deg. cent. initial temperature indicate those compression pressures at which the ignition point is reached in cold and warm engines. These points are surprisingly low and are only 6.1 and 7.3 atmos. The use, notwithstanding this, of very much higher compression pressures is due to the fact that the droplets of fuel need a certain amount of time to get warmed up to their ignition temperature, and in actual operation this warming must take place during the time it takes the crankshaft to move from 3 to 5 deg. The time between the beginning of injection and initiation of ignition has been called by Hawkes, who was the first to investigate this phenomenon, time lag. The author calls it "ignition lag" (*zündverzug*), and cites from Hawkes a curve plotted for a Scotch shale oil, showing the variation of this time lag with temperature at an air pressure of 14 atmos. at 500 deg. This lag is about $^1/_{100}$ sec., which seems to the present author to be too high. He considers the recognition of the time lag in ignition as a great advance, as together with the connection between the ignition point and pressure it permits the proper selection of the rate of compression.

MECHANISM OF COMBUSTION OF HYDROCARBONS

The question as to how the injected fuel burns in a Diesel engine after ignition has not yet been answered. We do not know yet precisely the composition of the fuel oils, and know only that they are very complex mixtures of hydrocarbons, are aliphatic, are obtained from petroleum or lignite tar, and are preëminently of two types, one of the composition C_nH_{2n+n} (paraffins) and C_nH_{2n} (olefins and naphthenes) of chain structure, and the other, aromatic compounds of ring structure produced from coal tar and belonging to the naphthalene, fluorene, phenanthrene, and anthracene groups.

Apart from the impurities always present, the gases of combustion of both kinds contain in general CO_2 and H_2O. It is certain, however, that combustion does not take place in a manner such that the fuel oil after ignition breaks up immediately into carbon and hydrogen, whereupon these two elements simply burn in the oxygen of the compressed air. Actually the combustion of the oils takes place through the intermediary formation of a large number of compounds which are different in the case of gas oils from those formed with aromatic hydrocarbons. As an example of this difference Franz Fischer cites the case of xylol on one hand and aliphatic gas oils on the other. These latter heated, apparently break up into smaller molecules, especially into ethylene, C_2H_4. This decomposition involves probably also the formation of methane, CH_4, since all hydrocarbons have a tendency to break up into this product and carbon. The mechanism of combustion of ethlyene and methane is now well known.

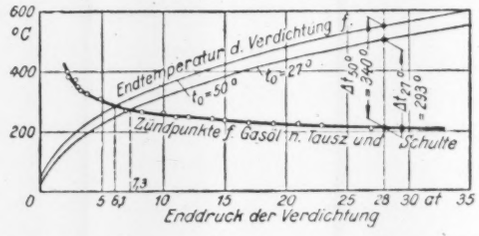


FIG. 4 END TEMPERATURES OF COMPRESSION AND IGNITION POINTS FOR GAS OIL

(*Endtemperatur d. verdichtung* = end temperature of compression; *zündpunkte f. gasöl* = ignition points of gas oils according to Tausz and Schulte.)

The author discusses next the combustion of carbon monoxide and refers to the work of Dixon and Wieland, the latter having shown that combustion of carbon monoxide involves intermediary formation of formic acid. Later investigators have, however, shown that hydrogen peroxide forms an indispensable step in the combustion of carbon monoxide, which itself is the last member in the chain representing the combustion of methane and ethylene, the materials into which the gas molecule decomposes during the combustion. This and their mechanism of combustion are next considered in some detail.

Should it be considered proved that gas oils break up in the process of combustion into smaller molecules, initially into ethylene and methane, it will be extremely likely that the mechanism of combustion indicated in this article will disclose also the final members of the combustion process. We do not know how many reactions precede the formation of these end members, and it is possible that the number of these reactions is very great. Furthermore, should it be found that ignition and combustion of the fuel oil in the Diesel engine take place in the manner here indicated, the question will still be open as to how the mechanism of combustion can be influenced in order to create a situation where the oils will burn to carbon dioxide and water vapor only. That actually other combinations are produced is well known, and one can easily obtain convincing evidence from the not uncommon smoky exhaust. Where the exhaust gases are not perfectly clear, soot particles are present and these, as shown by K. A. Hofmann and W. Freyer, are not pure carbon but hydrocarbons of complex molecular structure. In this case it would appear that the mechanism of combustion has been deflected into some undesirable bypath. To avoid this it is necessary, among other things, to arrange matters so that there shall be in the combustion chamber no heat-insulated parts capable of attaining temperatures above a certain limit, which for aliphatic fuel oils is about 600 deg. cent. Liquid droplets of fuel oil must not be permitted to come in contact with parts having such a high temperature, because if they do a kind of cracking takes place, the result of which is a sooty exhaust. The question of controlling the mechanism of combustion in the Diesel engine brings up also the important problem of mixture formation, which is a mechanical problem to a greater extent than is suspected today. (Dr. of Engrg. Fr. Sass, A.E.G., Berlin, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 71, no. 37, Sept. 10, 1927, pp. 1287–1292, 8 figs., *teA*)

Short Abstracts of the Month

AERONAUTICS

Recent Model Experiments in Aerodynamics

THE paper here abstracted describes experiments on air flow in relation to models, leading up from the fundamental ideas on the "boundary layer" of Prandtl through the study of comparatively simple systems like cylinders, rotating cylinders, and aerofoils, with side lights on the circulation theory of the aerofoil, to complex systems like the airscrew and the supporting screw of the Autogyro. Most of the experiments were carried out with models by the author himself and at a remarkably low cost. In addition to describing his own experiments the author gives data on the previous state of the art.

The action of a fluid flowing past a cylinder creates, under certain conditions, eddies which alternately attach and detach themselves from the body past which the flow takes place. The periodic detachment of these eddies causes a periodic alternating cross-flow on the body, tending to make it vibrate across the stream. If the body is wire tuned to the frequency of the detachment of the vortices, the wire "sings" this tone. These aeolian tones were first measured by Strouhal in 1878; he also established the fundamental formula connecting the width of the wire (= diameter of the cylinder D) with the frequency n of the tone and the velocity V of the stream, the formula being V/nD = a constant.

In the work described by the author he endeavored to evaluate this constant for as large a range of diameters as possible, and by as many methods as occurred to him. Among these is a method of his own devising in which a stationary wire is placed in a current of air instead of having the wire moving through a more or less stationary field.

The author also made experiments with wires in which an examination was made of their aeolian vibrations in a revolving water tank for comparison with the figures obtained with vibrations in an air current previously obtained. The subjects of dynamic similarity and effect of viscosity on the motion were also investigated. It was found that viscosity in the guise of the expression $Kf(VD/\nu)$, where ν is the kinematic coefficient of viscosity, determines when vortical motion shall commence, but once this motion has been initiated, has no effect on the period.

An effort was made to obtain photographs of the vortices in a liquid behind a swinging pendulum to show their relation with the movements of the latter.

The question of interference of walls of channel on eddying flow was next investigated with particular reference to frequency of the eddying and a formula given for this phenomenon, assuming that it is an aeolian eddy effect modified by interference of the outer tuber of the nozzle. It was found, however, that all the results do not fall on a unique curve.

The next problem tackled was an investigation on the Bénard vortices behind cylinders rotating about their axes. In this case the frequency of the eddy production was measured by the cooling effect on a hot wire. These experiments showed how rotation can be employed modifying the vortex production in the rear and providing a considerable lift/drag ratio. The paths of the vortices as they leave the cylinders were traced out by the instrument used (hot-wire detector) and are shown by curves in the original article.

The aeolian tones of brass model aerofoil sections have been determined by revolving-tank methods, principally with a view to obtaining values of the critical Reynolds' number for periodic detachment of vortices to occur. It was considered very important from the point of view of the theory of the aerofoil to measure the relative intensities of the vortices on either side on the aerofoil. The idea of the circulation of the rotating cylinder which is the direct cause of the lift diminishing the next circulation in these vortices has been more or less confirmed by the data obtained in tests with the hot-wire detector referred to above, Prandtl and Bjerknes suggested that the same theory applies to the aerofoil. If then the lift on an aerofoil is due to a circulation of this kind, one should expect prima facie an assymetry in the intensity of the vortices. No such assymetry is observed, however, it being found that the vortices were of equal strength on either side, though relatively closer than for the cylinder. In the measurement of the air flow in some of the tests a new method was employed, the principle being that the heating current is turned on to the hot wire for a fraction only but always at the same phase of each cycle of the airscrew, and at the same time the resistance attained is measured on a Wheatstone bridge. The type of anemometer here referred to can be applied to the measurement of any periodically varying air current by arranging that the contact maker shall revolve with the same periodicity. The results obtained with the airscrew and anemometer in question cover the following aspects: 1, Air flow through the "disk" at constant incidence, but varying speed of revolution; 2, air flow through the "disk" in different planes behind and before the airscrew; 3, air flow in different "working states."

By using a double hot-wire instrument in which the two wires are placed close together and parallel to each other it was found possible to determine the direction of the wind. This procedure afforded information regarding the impetus imparted by a revolving blade to a previously steady stream and the change in direction of the wind. This part of the investigation cannot be abstracted because of lack of space.

In the discussion which followed Dr. Piercy called attention to the surprising fact that aeolian tones were obtained at such low values of Reynolds' number as 30 for round cylinders and 50 for aerofoils. It was previously thought that eddies did not occur much below $VD/\nu = 100$. (DR. E. G. Richardson in *Journal of the Royal Aeronautical Society*, vol. 31, no. 201, Sept., 1927, original paper pp. 810–839 and discussion pp. 839–843, 28 figs., *teA*)

ENGINEERING MATERIALS

Rubber as a Material for Mechanical Engineering

THE main properties of rubber are that it is waterproof, a good insulator, very resistant to water and chemicals, and can be molded and otherwise fabricated readily. Its properties can be made to vary over a much wider range than can those of any other known material. To the engineer one of the most remarkable characteristics of rubber is its ability to permit an enormous change of shape when a load is applied, and to resume its original shape when the stress is removed. A piece of well-vulcanized high-grade rubber compound can be stretched to ten or eleven times its length without rupture or appreciable permanent deformation. Another property is the high tensile strength possessed by rubber. A piece of rubber, such as referred to above, may have a tensile strength calculated on the original cross-section of 5000 lb. per sq. in. The actual strength of such a sample at its breaking point is, however, about 50,000 lb. per sq. in. calculated on its cross-section at the time of breaking; since its tensile strength approaches that of steel.

Another interesting property of rubber is its ability to absorb energy. The original article shows a steel spring and a rubber band that have approximately the same elastic properties when not loaded. Another figure shows the elastic properties of the two when loaded. The author shows by a calculation how under certain conditions a 1-lb. piece of rubber absorbs the same amount of energy that could be absorbed only by a steel spring weighing from 50 to 100 lb. A bibliography of the subject is appended. (W. A. Gibbons in *The Journal of the Society of Automotive Engineers*, vol. 21, no. 3, Sept., 1927, pp. 262–264, 4 figs., *g*)

Rubber as a Material for Lining and for Joints of Pipe Bends

RUBBER has been employed lately as a material for lining ball mills. At first sight rubber would seem to be an unsuitable substance for this purpose, as it is difficult to imagine a rubber surface as being adaptable to the grinding of hard materials such as metalliferous ores. However, it would appear that in ball mills the grinding takes place mainly *between* the balls and not between the balls and the lining. By using a suitably prepared rubber the balls tend to imbed themselves in the rubber and are thus carried farther up the side of the drum than in metal-lined mills. The effective grinding area is therefore increased. The rubber lining being much lighter than a chromium- or manganese-steel lining, less power is required to set the mills in motion, consequently there is a saving

in power consumption; the lighter mill also means less wear and tear on the rollers and gearing, and finally the rubber lining lasts much longer than a hard steel lining, which means fewer interruptions and shorter stoppage of the mill for relining. As the time taken to fit a new steel lining in a mill is appreciable, the mill is out of commission for a much shorter time when steel is replaced by rubber.

The main difficulty in adapting rubber for this purpose was in anchoring it firmly to the surface of the drum without exposing bolt heads, clamps, or other metal attachments which would rapidly wear and result in the rubber becoming loose. This has been overcome by vulcanizing a steel channel piece in the rubber which provides means of positive anchorage to the shell with standard bolts. The lining is made up of a number of sections each consisting of an outer soft rubber layer with which the balls come in contact and an inner hard or semi-hard rubber vulcanized with the soft rubber in one piece and forming a bed for the outer steel rim. Each section is shaped so that the internal surface of the mill has a wave-like contour. Although a rubber lining enables mill speeds to be reduced 10 to 15 per cent without loss of output and a saving of power, experience has shown that it is preferable to maintain established speeds and reap the advantage of a better overall efficiency.

Experiments are also in progress with rubber sleeves for the joints of pipe lines. These sleeves should save bends, as the rubber being flexible and extensible would allow of the pipes being taken in any required direction merely by springing them. The use of rubber as a means of coupling up lengths of pipe to form pipe lines has been scientifically developed by the Victualic Co. who use a specially designed rubber ring clamped by a metal ring which compresses the edges of the ring against the ends of the adjoining pipes. The joint is suitable for water and air under pressure, and is so designed that the greater the pressure the closer will be the joint between the flange of the rubber ring and the pipe end. The joint is sufficiently flexible to allow of the pipe line being taken down the shaft of the mine and along the workings. When required the same line can be taken up and relaid elsewhere. For transmitting oil, rings of special rubber composition are supplied.

It is also possible to protect the metal surface of pipes by lining with rubber. Although this development has not reached a very advanced stage it has great possibilities. Experiments were made in the Federated Malay States on a tin mine. Mild steel pipes $^5/_{16}$ in. thick lasted only about seven months in spite of frequent turning to secure even wear. A section of this pipe was replaced by two half pipes made from $^1/_{16}$-in. galvanized mild-steel plate lined with $^3/_{16}$-in. raw crepe rubber and bolted together, with the result that after eighteen months' continuous use the rubber lining showed little or no signs of wear. (*Rubber and Engineering*, a special booklet issued by the Rubber Growers' Association, Inc., 2 Idol Lane, Eastcheap, London, E. C. 3, for the London Shipping, Engineering and Machinery Exhibition, Olympia, Sept., 1927, pp. 27–29, with 2 figs. illustrating the above abstract, *d*)

The Electrodeposition of Rubber

THE process of electrodepositing rubber has reached the commercial stage only very lately. It is based in part on the control of the transport of rubber and associated particles by an electric current and in part on the electrical control of the aggregation and consolidation of the particles. As anodes, metals which are anodically corrosible and form stable oxides compatible with the rubber deposit are preferred. With such anodes oxidative changes of the latex particles adjacent to the anodes are largely avoided. Zinc anodes have been found to be most useful, while copper anodes are unsatisfactory. Sulphur, fillers, pigments, and softeners in finely divided form can be added to the latex suspensions and the mixed compounds can be electrically deposited uniformly and substantially in the proportions of the mix. There is no necessary limit to the thickness which can be deposited, but the thickness is limited by the question of drying and by secondary changes in the surface layers. Rubber produced by electrodeposition may be vulcanized readily and permits also the use of so-called super-accelerators which cannot be used in milled stock, because they act so rapidly that scorching is produced. The tensile strength of electrodeposited rubber is exceptionally high. (S. E. Sheppard, Assistant Director, Research Laboratories, Eastman Kodak Co., Rochester, N. Y., in a paper presented at the General Meeting of the American Electrochemical Society, Sept., 1927. Abstracted from advance copy, pp. 93–127, 14 figs., *te*)

FUELS AND FIRING

The Economic Prospects of Fuel Oil

THE author attempts to explain why it is that a few years ago it was freely predicted that the end of our oil supply was in sight, while today the oil industry is suffering from overproduction. He quotes five reasons for this, the first being that today more use is made of geologic information, with the result that where not many years ago hardly one wildcat well in 150 flowed oil, today about one in three does.

The second reason applies chiefly to the Southwest and Gulf regions. There large areas long believed to be underlain by oil-bearing rocks had the latter hidden by overlying blankets of rocks of a much later age, and there was no way to locate with reasonable certainty the oil-bearing rocks. Recent geological methods, such as the use of seismographs and of microscopic investigation, have made it possible to render productive large territory at relatively reasonable cost. This has been one of the large sources of oil not counted upon a few years ago.

The third reason is improvement in cables and tools making possible the drilling of deeper holes—7000, 8000, and more feet—which opened to production strata not previously available.

The next reason for increased production is the use of artificial pressures which increase the flow of oil at least twice and possibly more as compared with what it would have been previously. The success of cracking is also a factor in this connection.

The author asks himself what the future will show. The outlook today is that present methods of production with the great surplus now on hand will serve all of our needs for several years—probably five years, and possibly ten. It may be anticipated that within relatively few years, probably within ten at the outside, production will begin to fall behind demand, and will do so much more rapidly than the old estimates had anticipated. For a time, with higher selling prices, the needs of this country will be met by importation from South America, and possibly elsewhere. Ultimately and before many years, however, we shall turn to oil artificially produced. At first this oil will come from oil shales, of which our western and middle states have vast reserves, probably enough to supply our needs for a hundred years, possibly for two hundred, if we assume that we devise more efficient methods of burning oil. The use of our oil shales as a source of oil means a higher cost and higher prices for gasoline and fuel oil, possibly thirty to forty cents for a gallon of gasoline, probably not over fifty cents. Ultimately, of course, even the oil shales will give out. But we know today that we can obtain oil from coal, and we have vast reserves of low-grade coal in our western states which has already proved admirably suited to the production of oil. (Geo. H. Ashley, State Geologist of Pennsylvania, in *Combustion*, vol. 17, no. 3, Sept., 1927, pp. 162–164, *g*)

The Utilization of British Coal Supplies

THE IDEAL utilization of coal supplies would necessitate the complete realization of the potential thermal and chemical values of coal, without the emission of smoke. Burning raw coal is an obvious failure to realize that ideal, and we are in revolt against it. On the other hand, if coal is carbonized, the two principal products, gas and coke, are smokeless fuels, while the tar and ammonia are valuable chemical by-products. Carbonization is a standard industry, as carried out in gas works and coke ovens, and there are other well-known processes of gasification.

The position at present may be stated thus: In 1924, according to the report of the Secretary for Mines, the allotment of 180 million tons of coal available for home consumption may be made approximately as 16.7, 7.7, and 100.3 million tons for gas works, electricity generating stations, and domestic use, respectively, and for the carbonization industries, taken together, gas works and coke ovens, 32.9 million tons. It is interesting to consider what are the factors at present limiting the applications of carbonization or similar processes to the great bulk of our coal supplies, and what is being done, or may be done, to remove those limitations.

The outstanding technical factor limiting the economies of carbonization seems to be that of speed in operation. The burning of carbon by air at the temperature of a good boiler fire can take place at a speed which is limited solely by the rate at which air can be brought into effective contact with the carbon. Combination is, to all intents and purposes, instantaneous and complete. The position is quite different in carbonization, even in such processes as the gasification of coal in steam and air in a producer for the manufacture of producer gas, or of coke in steam for the manufacture of water gas. There, the processes of heat penetration and the reactions of gasification are very much slower. The consequence is that much higher expenditure on the plant and its working, per ton of coal have to be incurred.

It is not strange, then, that in one way and another, a vast amount of work is being applied to determine how these reactions of coal and coke, other than their direct burning in air, can be accelerated. In the case of an ordinary plant, the heat has to be transmitted through the wall of a fireclay retort, and then through the mass of coal. It is a slow process. The retort, for high-temperature working, is made of fireclay of low conductivity. Heat in penetrating the coal is partially conducted by the solid, and partly radiated across spaces between the solid particles. Some heat is also convected from point to point of the charge by the gases evolved during carbonization. The condition of affairs is complicated, since it is not only heat transmission which is important, but also keeping the charge in such a condition that the volatile products may be evolved as easily and escape as quickly as possible. Such considerations are responsible for much experiment in design and treatment. Narrower retorts or tubes have been tried, and fireclay replaced by the iron employed in the older days of the gas industry. Careful inquiry has been directed to find the type of iron which will not suffer from the growth and distortion which ruined the old retorts. Other alloys, such as "Cronite," have been used experimentally with considerable success, as the author can say from first-hand experience, although the cost of "Cronite" is too high to allow of its general use in large-scale work.

The use of metal, as compared with such refractory materials as fireclay or silica, has, however, one disadvantage, in the sense that it imposes a much lower limit upon the temperature of the combustion chamber. This has the effect of lowering the temperature head available for rapid working. The present tendency in gas-works and coke-oven practice is to use a high quality of refractory material, usually silica, in order to get as high a temperature head as possible between the combustion chamber and the charge. There is much to be said for seeking to produce the material sometimes known as semi-coke, containing a certain proportion of volatile matter, not by simply carbonizing of set purpose at a lower finishing temperature (what is usually understood by low-temperature carbonization), but by rapid incomplete carbonization at a high temperature. To bring that about, everything must be done to facilitate the penetration of heat and the escape of volatile matter. The condition of the charge at every period of its carbonization should be the best possible.

The author next speaks of something more speculative in character, but worthy of consideration. It is open to us to make progress not solely by an alteration of the thermal and mechanical treatment of coal, but by modifying, if we can, its chemical behavior and reactivity. We need not assume that coal, as it has been naturally deposited, is in the best chemical condition for use, and that there are no practicable means of stimulating its reactivity—of inducing a different behavior during carbonization from the natural to the coal as it is mined, and imparting where desired greater reactivity to the resulting coke. How far is it practicable to catalyze the reactions with which we are concerned in the carbonization and gasification of coal? Dr. Lessing has pointed out that the behavior of coal during carbonization in the laboratory is affected materially by the presence in small quantities of many inorganic compounds, and Haber suggested that the ash of coal might catalyze the reaction of gasification in steam.

Further investigation has clearly shown that if we consider such oxide constituents as commonly occur in the ash of coal, alumina and silica which usually occur in the greatest quantity these have little or no effect but lime, oxide of iron and soda materially influence the process of carbonization. This is very apparent on the laboratory scale, where much finer-grained, stronger, and more homogeneous cokes have been produced by the addition of 5 per cent of these materials. The full explanation is not forthcoming, but it would appear that the evolution of volatile matter during the plastic stage is slowed down, and the puffing-out and honeycombing of the coke are lessened on that account. On the larger scale, these special cokes are, however, not obviously different in structure from pure coke made without additions, presumably because the process is in any case so much slowed down that the differences are smoothed out. It is likely that in processes of rapid carbonization on any scale, they will be retained. There are some interesting points in the larger-scale results. Thus, the gas yield was increased 20 per cent with a sodium-carbonate coke, and the ammonia yield by 35 per cent with a calcium-carbonate coke. But what is of greatest importance from our present standpoint is the interesting change, which has been brought about, on both the laboratory and the large scale, in the properties of the coke by these additions. The following are one or two illustrations: On gasification in steam, the laboratory equivalent of the water-gas process, the cokes made with alumina and silica additions behaved exactly like the pure coke, but the cokes made with lime, oxide of iron, and particularly sodium carbonate, behaved quite differently. They gasified much more quickly, and gave a much better water gas.

It may be pointed out that as the rate of steam passage through a bed of red-hot coke is increased, some of it begins to come through undecomposed, and the water gas, instead of being practically all carbon monoxide and hydrogen, contains CO_2 in gradually increasing quantities. With the pure coke in the laboratory apparatus at 1000 deg. cent., using 10 grams of coke, the gas made contained 5.2 per cent of CO_2 (taken as a permissible amount) when the rate of steam supply was 2.5 liters per hour, and the coke was being gasified at the rate of 1.15 grams per hour. With the silica coke, the figures were practically the same. With the iron oxide coke, the rate of steam supply had to be increased ninefold, to 21.9 liters per hour with a coke gasification of 10.5 grams per hour, before the CO_2 in the gas amounted to 5 per cent. With the calcium-oxide coke, a CO_2 content of 5.4 was obtained with a rate of steam supply of 11.2 liters per hour, and a coke gasification of 5.2 grams per hour. The figures obtained with sodium carbonate were even more remarkable. With a steam supply of 21 liters per hour, the CO_2 was only 4.4 per cent, and in order to get 5 per cent of CO_2 in the gas, it was necessary to make the column of coke only one quarter of its original length.

It is plain from these figures, that the reactivity of coke to steam was so far enhanced by the additions, that the rate of working could be increased tenfold, or more, without impairing the quality of the gas made. These results were obtained at a temperature of 1000 deg. cent. At lower temperatures, the influence of the added constituent was, in some ways, even more remarkable. It is to be remembered that the maintenance of such a temperature as 1000 deg. cent. in all parts of the fuel bed is not practicable in many gasification processes, and that, for example with steam, the rate of gasification falls off rapidly with temperature, and the quality of the gas made is lowered by the production of a greater amount of CO_2.

Perhaps one of the most striking examples of the influence of an added constituent was obtained by the comparison of the behavior, at 800 deg. cent., of a pure coke and a sodium-carbonate coke, with the steam supply at 10 liters per hour to 10 grams of coke. With pure coke, 0.9 gram of coke were gasified per hour, yielding a gas containing 18 per cent of CO_2. With the sodium-carbonate coke, 5.8 grams were gasified per hour, and the gas made contained only 1.7 per cent of CO_2, which represents six times the rate of gasification with only one-tenth as much CO_2 in the gas. This enhanced reactivity of coke toward steam is obviously of direct importance in the making of water gas, and the steaming of coke in gas retorts, and also in nearly all gas-producer practice, where coal and coke are gasified in air and steam, since, even if the producer is charged with coal, as is most commonly the case, expulsion of volatile matter at the top of the producer soon converts the coal to coke, and it is the gasification of coke with which we are concerned, as being responsible for the great bulk of the gas made.

Summarizing, the author's main thesis is that one great reason militating in practice against the replacement of the direct burn-

ing of coal by methods which would be more scientifically economically, and hygienically satisfactory, is that none of the other processes of transforming coal is anything like so rapid as that of direct burning. Consequently, much is being done, and more remains to be done, in investigating, on the laboratory and on the large scale, how the speeding up may be effected. The investigation is necessarily taking many forms, through the design of apparatus, the study of the nature of coal in the molecule and in the mass, in order to understand its potentialities under many thermal and chemical conditions, and the inquiry into the possibilities of modifying the properties of coal in directions found desirable by suitable additions. (J. W. Cobb in a paper read before Section G of the British Association at Leeds, September 2, 1927. Abstracted through *Engineering*, vol. 124, no. 3217, Sept. 9, 1927, pp. 341–342, *gp.*)

INTERNAL-COMBUSTION ENGINEERING

The Foos High-Speed Diesel Engine

DESCRIPTION of a type intended for application to power shovels, locomotive cranes, industrial locomotives, etc. and built by the Foos Gas Engine Co., Springfield, Ohio. The speed range of this engine extends from 400 to 900 r.p.m. Following automotive practice the engine is completely enclosed, no moving parts except the extension shaft coupling being visible and even the flywheel being under cover. The engine operates on the full Diesel cycle and is equipped with the standard-type combustion chamber, the cylinder head being completely flat and there being no recesses or precombustion cups. Mechanical injection is used.

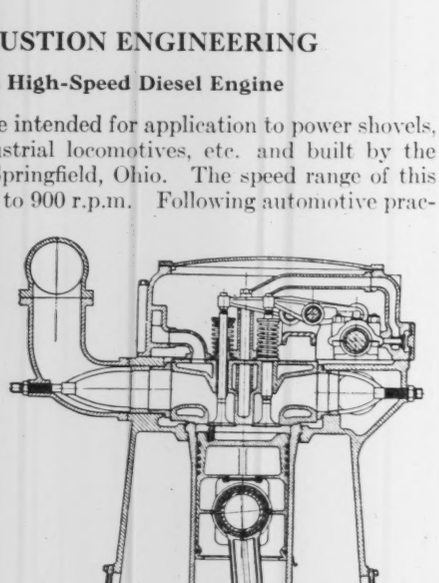


FIG. 5 CROSS-SECTION OF A SINGLE CYLINDER OF THE FOOS HIGH-SPEED DIESEL ENGINE

Because of operation at a higher range, particular attention had to be paid to the design of the valve gear. Two exhaust and two inlet valves in each head are used with rocker arms actuated by camshaft control for both types of valves. A single layshaft running the full length of the engine at the level of the cylinder head provides the drive for the valve control. The cross-section shown in Fig. 5 illustrates some of the details of construction. The Foos Diesel engine is built in units of from 2 to 8 cylinders with a bore and stroke of $8^1/_2 \times 11$ in., covering a power range from 45 to 475 b.hp. The two-cylinder unit, for example, develops from 40 hp. at 400 r.p.m. to 100 hp. at 900 r.p.m. and is said to weigh just under 6000 lb. (Morris A. Hall in *The Automotive Manufacturer*, vol. 69, no. 5, Aug., 1927, pp. 5–7, 3 figs., *d*)

MARINE ENGINEERING

A Swiss Marine Steam Engine with Oil Hydraulic Valve-Gear Control

DESCRIPTION of the power plant of the steamer *Helvétie* described in MECHANICAL ENGINEERING, vol. 49, no. 9, Sept., 1927, p. 1023, in abstract from *The Engineer*. (*Schweizerische Bauzeitung*, vol. 90, no. 11, Sept. 10, 1927, pp. 135–139, *d*)

POWER-PLANT ENGINEERING

Water Treatment

THE present paper deals with the problem of zeolite water treatment in a large central heating plant and gives, among other things, operating results showing the water condition before and after treatment and at various points in the cycle.

As a pure experiment, to determine the possibilities of further decreasing the CO_2 content of the steam, some phosphoric acid was used for a short period in addition to the sulphuric acid. The results are shown in a table in the original article. With a feed of 41 parts per million of H_2SO_4 plus 24.6 parts per million of H_3PO_4, the carbon dioxide in the steam was reduced to 12 parts per million. The pH value of the water after the acid treatment was 5.8, and that of the condensed steam was 5.4. Although the sulphate-carbonate ratio is above the limit suggested by Dr. Hall, the present PO_4 content is 150 p.p.m., whereas a concentration of somewhat more than 4 p.p.m. should be sufficient. These results indicate that it is entirely possible to control the carbon dioxide content of the steam by varying the acid feed, and that the use of phosphoric acid for this purpose appears quite feasible, although experience with it has been very limited.

The following are among the conclusions arrived at by the authors:

The present addition of sulphuric acid sufficient to neutralize about 50 per cent of the $NaHCO_3$ in the zeolite-treated water gives a pH value of 6.4 to the water entering the deaerator and a pH value of 8.5 to the water leaving the deaerator and entering the boiler.

The water leaving the deaerator has lost all of the CO_2 set free by the acid, and the amount of $NaHCO_3$ which was 60.5 p.p.m. after the acid treatment has dropped to 38.5 p.p.m.

The ratio of sodium sulphate to total alkalinity is believed to be amply safe with the amount of H_2SO_4 added.

Inspection of the boiler after eight months of operation has revealed clean tubes and no serious corrosion. There have been no tube burn-outs.

It has been demonstrated that the use of additional acid in the form of phosphoric acid gives less carbon dioxide in the steam and less caustic alkalinity in the boiler. The necessity of thus reducing the carbon dioxide is not certain and will be justified only if the steam shows itself later to be corrosive with the smaller amount of acid feed. If scale ultimately appears in the tubes when only sulphuric acid is used, it is believed that the addition of a small amount of phosphoric acid will eliminate it. (Paper by Alfred H. White, Professor of Chemical Engineering, University of Michigan, J. H. Walker, Asst. to Chief Engineer, Detroit Edison Co., Everett P. Partridge, Fellow in Chemical Engineering, University of Michigan, and Leo F. Collins, Chemist, Detroit Edison Co., before the convention of the American Water Works Association, June, 1927, abstracted from separate publication, 27 pp., 10 figs., *e*)

A Device for Detecting Traces of Mercury Vapor

IN VIEW of the employment of mercury-vapor turbines in power plants, the detection of mercury leakage to the atmosphere becomes of interest to mechanical engineers. As small a proportion as one part of mercury in 20,000,000 parts of the atmosphere can now be measured accurately, and one in 8,000,000 parts can be determined quickly.

The principle of operation is based on a reaction between a solid substance, selenium sulphide, and the mercury vapor, with the reaction product a colored substance easily observable with the eye. The yellow selenium sulphide is applied as a coating on paper. The paper is blackened on exposure to air containing mercury vapor, the degree of blackening depending on the concentration of the mercury, the time of exposure, and various other factors which can be definitely controlled. There seems to be practically no lower limit to the concentration that can be detected by this method.

For continuous and automatic registration of the mercury vapor, there has been devised a system in which a continuous strip of the coated paper is drawn slowly over an opening through which the air flows, a small clock motor moving the strip of paper at a uniform rate. A short time after the exposure, the colored strip of paper can be compared with a standard scale, in which the different shades

from yellow to black have been calibrated in terms of mercury concentration.

If an incandescent lamp is placed in front of the strip of paper and a photoelectric cell behind it, the amount of light reaching the cell will depend on the amount of blackening of the paper. The transmitted light can regulate the readings of an ammeter, so that the concentration of the mercury vapor can be determined either by observing the color of the paper or by reading the ammeter. It is also possible to so arrange the photoelectric-cell circuit that, should the mercury concentration become dangerously high, a warning signal will be given. The device, which in this form is an automatic chemist, was developed in the Research Laboratory of the General Electric Company. (*General Electric Review*, vol. 30, no. 9, Sept., 1927, pp. 442, *g*)

The Economic Position of the Mercury Turbine

THE results obtained at Hartford have led many people to the conclusion that by the use of this mercury unit the electrical industry will be able to cut its production costs markedly. The fallacy of this belief is shown in a recent analysis made by the firm of Arthur D. Little, Inc., of the available supplies of mercury and the effect of its increased use on the cost of this technically ideal but scarce metal.

From a low point of $0.53 per lb. in 1913, mercury rose to a price of $1.10 in 1925. During this period the annual consumption in the United States increased from 1,630,000 lb. to 2,230,000 lb., showing the sensitiveness of the price of mercury to increased demand.

The mercury-steam unit generates two-thirds of its power with steam and one-third with mercury and requires approximately 15 lb. of mercury per kilowatt of electricity so generated. This means that if the mercury-steam turbine were to take care of an assumed annual new generating requirement for the electrical industry of 2,000,000 kw., about 10,000,000 lb. of mercury would be needed each year. This is a figure some five times the present total consumption of mercury for all purposes in the United States to merely take care of the normal yearly increase in electrical generating capacity.

Mr. Little estimates that if Emmet units were to take care of only one-fifth of the new generating capacity, mercury would sell at $2 per lb. On this basis the capital cost per kilowatt for mercury would be $30, which, based on $4 coal, an average annual load of 220 kw-hr. per kw. of capacity and the use of 2 lb. of coal per kw-hr., would yield 17 per cent return on the additional mercury investment—a very worth-while saving, indeed, but not large enough to be revolutionary in reducing the cost of producing electricity. (*Gas Age-Record*, vol. 60, no. 10, Sept. 3, 1927, editorial on p. 321, *g*)

REFRIGERATION

Balancing Compressor Power and Condenser-Water Costs

THE author isolates the factors considered and attempts to arrive at a tangible result. In a refrigerating installation the purpose is to maintain a known or fairly well-fixed brine temperature. The actual suction load may vary, but to all intents and purposes the back pressure of the compressor remains fixed and constitutes a basis of calculation for any given installation. The other most important factor is the condenser temperature, which is a seasonal variable by nature and also subject to variation due to operation and condenser-water regulation. As shown by a curve in the original article, the relation of power increase to water circulation is approximately a hyperbolic function. The selection of a water quantity very far from the apex of the hyperbola gives absurd results, and it would appear that the quantity of condenser water per ton used in general practice averages at the most economical level from 1 to 6 gal. per min. per ton. There are conditions of cost, however, which may warrant in different localities the selection of quite different quantities of water circulation.

This paper is primarily concerned with temperature heads. In effect, it attempts to maintain the least difference between head pressure and back pressure without wasteful sacrifice of condenser water. It is not directly concerned with the capacity, or tonnage loading of the refrigerating machine, except in so far as it affects the efficiency of that machine.

The power consumed in compressing against the increment of temperature head controlled by the condenser-water quantity is termed by the author the "flexible temperature increment of condenser power." The most economical condition of operation, with the available resources, is then contingent upon the cost of this increment of power plus the cost of the condenser-water circulation being a minimum.

Let t_1 = saturated suction temperature
t_c = saturated condenser temperature
t_d = temperature difference of condenser water in and out
t_w = initial condenser-water temperature
t_x = temperature difference, condenser gas and final condenser water = $t_c - (t_w + t_d)$
m = slope of power curve, or horsepower increase per ton per degree increase in condenser temperature. (Slope of the power curve resulting from dividing the adiabatic power curve by E_v, the efficiency E_v considered affecting only the actual compressor power and not the slope of the power curve)
E_v = volumetric efficiency
E_c = mechanical efficiency of compressor
E_d = efficiency of driving unit
E_1 = $E_c \times E_d$
W_c = compressor i.hp. per ton
H_c = heat to be removed in condenser per min. per ton = $200 + 42.4 W_c / E_1$
G = condenser water per ton = $H/8.33\ t_d$
A = cost of power per hp-hr. input
B = cost of cooling water for the condenser per 1000 gal.
F = water pumping head in feet = static head F_s + friction head f
E_p = combined water-pump and motor efficiency
f = circulating-water friction head, in feet = $K(D/t_d)$ where
K = constant giving a circulation friction corresponding to an assumed temperature difference D, and
D = assumed value of t_d for relative friction K

The difference between the saturation temperature corresponding to the condenser pressure, and the leaving condenser-water temperature may be taken as a constant within reasonable limits for a given ratio of load to surface. Let it therefore be assumed that with a reasonable temperature variation of the condenser water range t_d in and out, the condenser saturated temperature t_c will vary proportionately. That is, the flexible temperature increment of compressor power, $\Delta W_c = m \Delta t_d$, where m equals mean slope from $(t_c - t_d)$ to t_c.

The condenser water used per minute per ton $= G = \dfrac{H_c}{8.33\ t_d}$ gal.

In both of the above expressions there are variable factors, the exact determination of which in actual practice may be rather difficult. These factors are W_c or m, and H_c.

Charts are given in the original article showing the variables for what are considered to be approximately average operating conditions for ammonia in piston compressors.

The author proceeds next to the consideration of plant operation, either by purchased water or pumped water. This part of the paper is not suitable for abstracting. In both cases he gives expressions for the operating power. In the case of power water he shows that the combined power curves are very flat near the optimum operating condition, showing that the water rate can vary considerably without materially affecting the operating economy, assuming the same size of equipment. (R. W. Waterfill, Newark, N. J., in *Refrigerating Engineering*, vol. 14, no. 3, September, 1927, pp. 93–97 and 103, 10 figs., *tc*)

SPECIAL MACHINERY

British Rolling-Mill Practice

A DESIGN of a British mill coupling is shown in Fig. 6 which is in reality a large and special coupling box of universal design. The full bearing surfaces of the machined phosphor-bronze driving blocks are available since there is no possibility of distorting the

line of the drive. There are two blocks on the end of the forged steel driving crabs, giving a perfect couple and insuring pure torsion on the sleeve, which is sometimes made in halves with solid registers so that it can be taken apart at any time without dismantling the pinion housing. Should there be wear on the faces of the blocks these can be readily adjusted. As a matter of fact, however, one such drive has been in operation ten years without any need to take up wear.

Another strong point is that it is really a universal coupling in that it can drive with full efficiency even if the shafts are not in alignment. This is by no means a negligible property, because it obviates the drawbacks of inaccurate setting-up or any settlement in the foundations after erection. Should either occur, this coupling will continue to drive, and as the whole coupling is made of cast or forged steel, with the exception of the phosphor-bronze blocks, it is practically indestructible. It may be stated that the other design has given trouble, and in at least one case broke down completely, causing an expensive shutdown of the mill plant. The next item is the pinion housing, about which little special claim can be made except in material and workmanship, but all pinion housings with one exception (and that British) have failed to provide adjustment in both the horizontal and vertical directions. In point of fact, the orthodox way has been to adjust in a vertical direction, in which the weight only is acting; whereas in the horizontal, where there is no adjustment, the working load of the mill pinions has to be met, and this load in the largest mills reaches 400 tons. In the design which allows for horizontal adjustment the bearings are made in four parts in the same manner as the main bearing of an engine crankshaft, and all adjustments can be made externally without any dismantling. No foreign-made or foreign-designed mill has this property.

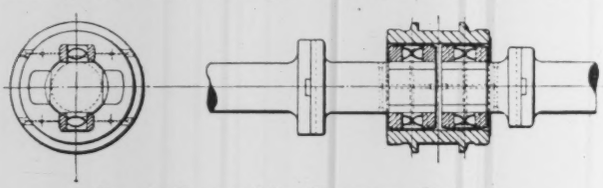


FIG. 6 BRITISH MILL UNIVERSAL COUPLING

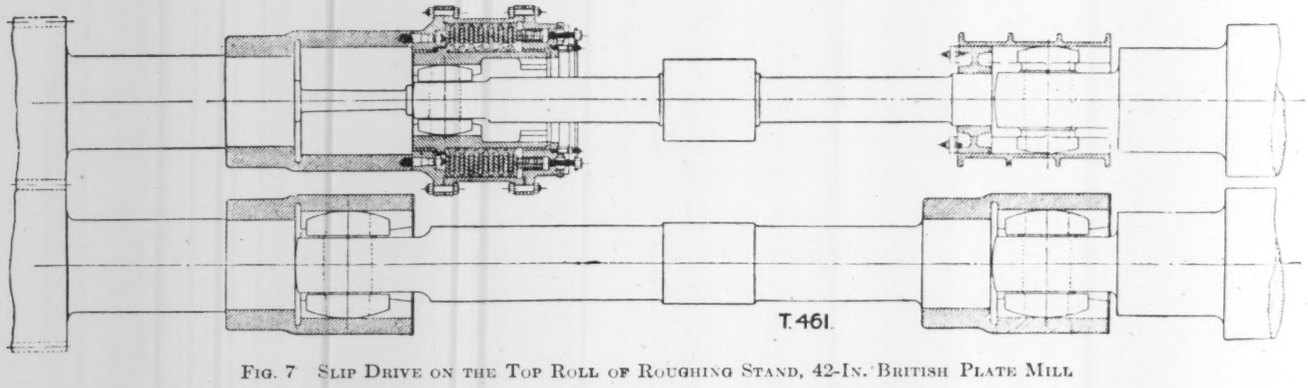


FIG. 7 SLIP DRIVE ON THE TOP ROLL OF ROUGHING STAND, 42-IN. BRITISH PLATE MILL

These pinions and housings, with their attendant bedplates and oiling gear, run into thousands of pounds, and in addition it is necessary to keep a spare set of pinions and other details to effect repair when breakdowns take place. In one mill which has been running a little more than two years a complete set of pinions is now required.

It has now been proved by actual experience in England over a considerable period that pinions of a power required to transmit the full torque of the mill are not necessary. Fig. 7 shows the application of a slip drive on the top roll of a roughing stand of a 42-in. plate mill, and the difference in size between the upper and the lower spindle indicates the reduced torque which is required to be transmitted when this gear is attached. This means that the pinions of the usual strength can be eliminated, and a pair of quite small gears inserted equal to about 15 per cent of the mill torque instead of 100 per cent.

In addition to reduced first cost and spares there will be no broken pinions, because when the shock of the entering piece which could have been transferred to the mill pinions occurs, the slipping surfaces come into operation and the shock does not reach the toothed gears. In addition, there is reduced power consumption.

This gear has also been attached to the finishing stand of a 42-in. plate mill with complete success, and by obviating the heavy shock when the plate enters or leaves the rolls, there is no danger of the breaking of rolls which is so common from this cause. This gear is so successful that a plate can enter and leave the rolls when running at 1000 ft. per min., and the mill can roll plates down to a thickness of $\frac{1}{8}$ in. with a length of 100 ft. This feature was in use in England several years before it was taken up in America; it is protected by patent in this country.

One of the strong claims of the drive, no matter what type of mill, is that rolls of unequal diameter can be used constantly without causing any distortion to the plate or section, and any roller knows what an advantage this means.

The article also describes and illustrates a new type of patent universal spindle which, it is said, can be applied to any steel-mill roll. The responsibility for the statements made rests with the author of the original article and not the abstractor. (F. H. R. in *Mechanical World*, vol. 82, no. 2124, Sept. 16, 1927, pp. 200-202, 6 figs., *d*)

The Keenok Variable-Speed Gear

THE Keenok pinion and gear shown by the Keenok Company, Ltd., 1-9 Eleanor Street, London, E. 3, represent a means of obtaining an infinitely graded speed variation between a driving and a driven member. The system employed is not of the positive type. The speed variation is obtained on the well-known principle of running the edge of one wheel on the face of another, and by setting the first wheel nearer toward or further away from the center of the second wheel, according as a lower or a higher speed is required in the driven member.

Let us take it that the edge-running wheel is the driven member. It is evident that if the driving member runs at a constant speed, and if the power transmitted is constant, the force to be transmitted by friction between its face and the edge of the driven wheel must increase as the driven wheel is moved inward to reduce the speed. If the pressure between the two members is just sufficient to give the required frictional force when the driven wheel is at the maximum radius, then that wheel will inevitably slip when it is moved in to reduce the speed. If, on the other hand, the friction is sufficient to prevent slipping when the driven wheel is at the minimum radius, the pressure between the two members will be altogether excessive when the driven wheel is at its maximum radius. It is evident that theoretically this form of speed varying gear requires that the pressure, and therefore the friction between the two members, should increase proportionately as the driven wheel is moved inward toward the center of the driver. The Keenok pinion is claimed to give automatically the exact variation of pressure required.

The pinion—Fig. 8—the driven member referred to above, consists of a hardened steel tire placed to move easily between two disks. The disks are pinned to a central member keywayed for attachment to the driven shaft. The periphery of the central member is serrated with shallow V-grooves in each of which there is placed a hardened steel roller. The tire of the pinion bears

against the face of a plain hardened steel disk on the driving shaft, and arrangements are provided for moving the pinion to different radial distances on the driving member.

The tire has a freedom of one or two thousandths of an inch on the ring of rollers, and as initially set at the maximum radius on the driving member is caused to exert on that member a regulated amount of contact pressure. Under this pressure the tire assumes a slightly eccentric position relatively to the rollers and the central member of the pinion. The tangential force received on the tire from the driving member causes the rollers on the contact side of the pinion to roll slightly up the slopes of the central-member serrations. In so doing they tend to restore the tire to concentricity and to increase therefore the pressure with which the tire makes contact against the driving disk. It is fairly evident that the greater the tangential force applied to the tire, the farther will the rollers climb up the slopes of the serrations and consequently the greater will be the pressure exerted by the tire against the driving disk. It follows, therefore, that as the driven member is moved nearer to the center of the driving member to reduce the speed the contact presssure rises in keeping with the increased tangential force which has to be transmitted. So complete is the correlation between the contact pressure and the tangential force that, it is stated, the driving and the driven members may be, and in practice normally are, run in an oil bath without the least slip occurring between them at any speed setting.

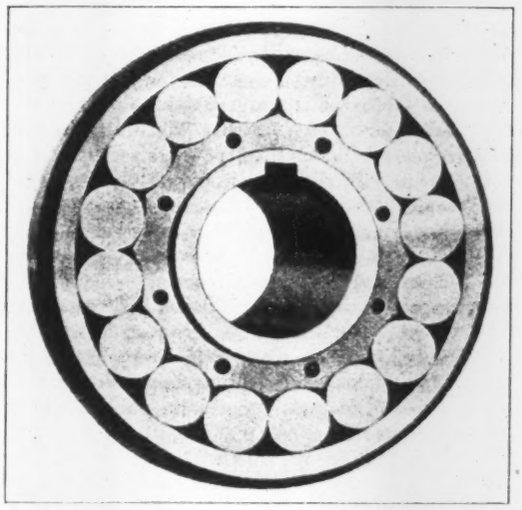


FIG. 8 THE KEENOK PINION

The term "pinion" may appear at first sight a little misplaced as applied to a device of the kind described. It is, however, justified by the fact that the device may be run with its tire in contact with the edge instead of the face of a plain disk driving member. It and the driving member thereupon become the equivalent of two gear wheels in mesh. The speed ratio in such an arrangement is not of course variable, but the advantage is secured that the wheels are toothless. No slip will occur between them, for the contact pressure rises, as in the other arrangement, in keeping with the tangential driving force applied to the tire.

A face-and-edge running change-speed gear box is shown in Fig. 9 (internal arrangement). A very considerable amount of interest is to be found in the means employed to vary the radial position of the driven member on the face of the driver. Since the tire has appreciable thickness, and is not a mathematical plane, there can be only one plane in its width, which will run without slipping on the driving-disk face. If this plane be the central plane, then at any setting the inner edge of the tire must over-run and the outer edge under-run the circles of the driving disk with which they are in contact. If the line of contact is radial with the driving disk the driven member, as matters are arranged in the actual gear, will have no tendency to move across the face of the driver. If, however, the line of contact is not radial the driven member will tend to move toward or away from the center of the driver, according to which side of the radial line the line of contact is tilted.

The driven member is bored to rock on the driven shaft. It is tilted through a connection which it has with a shaft, one portion of which is made slightly eccentric. A handle is provided for rotating the shaft, and when this handle is turned the driven member is tilted, and creeps to a new position on the face of the driving disk. The radial motion stops when the handle is restored to the normal position. In its radial motion the driven member carries with it the eccentric shaft and a rack attached to it. The rack meshes with a pinion on a spindle carrying a pointer. The position of the rack reflects the position of the driven member, and consequently the position of the pointer indicates the speed of the driven member. In some applications a positive means of moving the driven member replaces or supplements the semi-automatic control already described. A locking device can be fitted to preserve the position of the driven member at any set point. In other designs a double driving arrangement is provided to render the transmission parallel instead of at right angles.

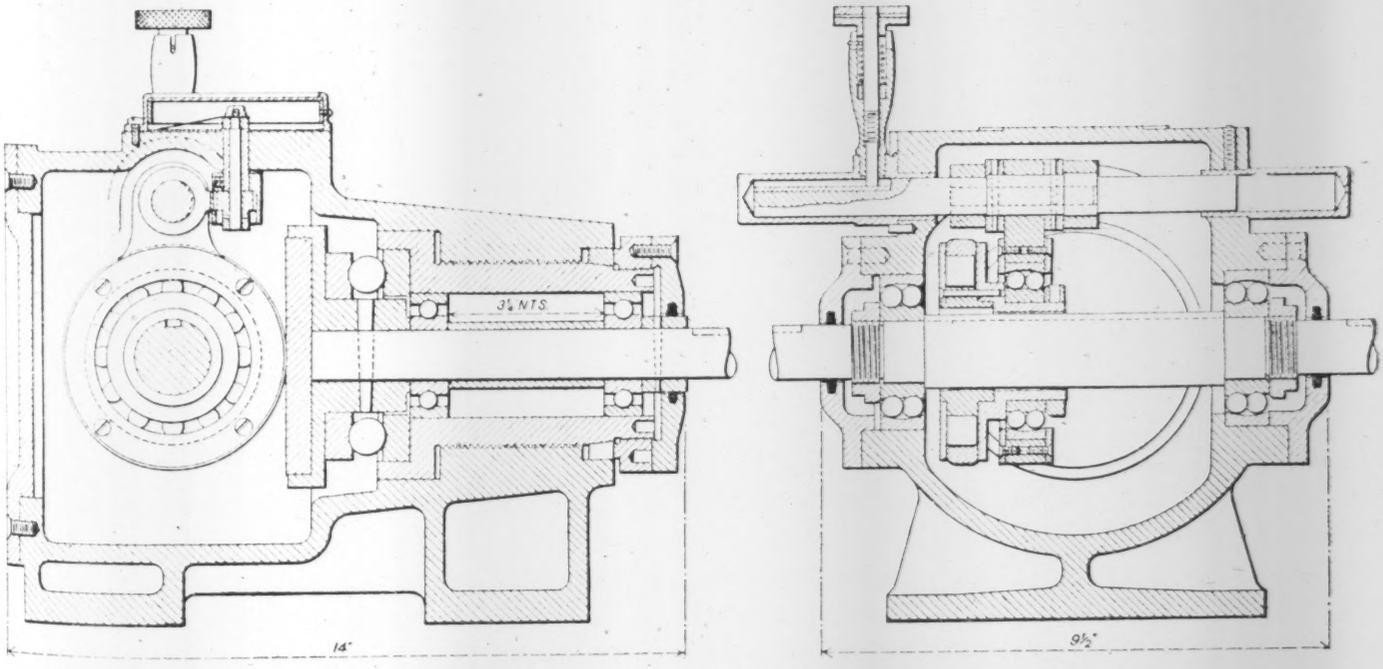


FIG. 9 INTERNAL ARRANGEMENT OF KEENOK CHANGE-SPEED BOX

The range of speed variation obtainable depends upon the diam-

eters of the two members. It is stated that with a 5-in. driving disk and a 4½-in. driven member it is quite practicable to obtain a range in the driven member from equality down to a tenth of the driving-member speed. The performance of the gear may be judged from some particulars furnished regarding an example having a 4¾-in. disk and a 4½-in. pinion running in oil. The driving motor was of 9 hp., direct current. A load of 360 in-lb. was applied to the driven shaft, and although it was far from steady, no trace of slip was observed. The load was then suddenly increased to about 1000 in-lb., with the result that the motor was pulled up dead. Another gear was run 8½ hours per day for three months. On being dismantled, it is said that it showed no diminution in diameter as judged by a micrometer. The surfaces of the tire and disk and the ball races were found to be in excellent condition. (*The Engineer*, vol. 144, no. 3741, Sept. 23, 1927, p. 336, 3 figs.; from an account of the exhibits at the Shipping, Engineering and Machinery Exposition, Olympia, September, 1927, London, *g*)

A New British 15-Arm Automatic-Suction Bottle Machine

A BOTTLE machine has to work under what the author calls barbarous conditions, and this applies particularly to a machine making common bottles on mass production lines. There are heat, dirt, carbonized oil, particles of glass and wear and tear to contend with. The machine has to work throughout the whole 24 hours, week after week and month after month, as long as the furnace holds up. If bottles are to be supplied at a competitive price in these days, one must have a machine which requires the minimum of attention and involves the least possible loss of production. The cost of keeping a furnace going is so great that the engineer has to aim at producing a machine which will continuously stand up to its job and pour out an endless stream of bottles.

There are two types of bottle machines, those in which the glass is fed by gravity and those where it is done by suction. Which type is best is still a debatable matter, but the latter has been selected here. The machine consists of the general structure and 15 arms, each of which is to all practical purposes a separate bottle-making unit. Each is complete in itself and consists of all those moving parts essential to the making of the bottle. In case of a serious breakage ever occurring in any unit it can be taken out of the machine and another complete unit put in, perfectly adjusted and ready for the machine to be going again in 45 min. Because of this multiplicity of producing units, it is possible to have a number of sizes and shapes of bottles made at the same time. The variation in weight of the bottles would depend on glass conditions, temperature, and the skill with which the mold equipment was designed.

The machine is of a very substantial size. There are approximately 40 tons of moving parts mounted on the stationary element, and the whole machine weighs about 60 tons. The machine is revolved up to speeds between six and seven revolutions a minute and is electrically controlled throughout. By means of an electromagnetic brake automatically applied, it can be brought to rest from a speed of 6 r.p.m. within 2½ ft. The original article describes the construction in detail. (Francis Redfern in *Journal of the Society of Glass Technology*, vol. 11, no. 42, June, 1927, pp. 257–265, 13 figs., *d*)

VARIA (See also Power-Plant Engineering: A Device for Detecting Traces of Mercury Vapor)

The Seminole Air Lift Society

IN A PREVIOUS issue of MECHANICAL ENGINEERING (vol. 49, no. 9, Sept., 1927, p. 1022) reference was made to the use of air lifts for increasing the flow of oil in the Seminole field. Lately the Seminole Air Lift Society was formed for the exchange and dissemination of ideas and information relative to air-lift work, particularly in the Greater Seminole district. The first meeting was held at Tulsa, Okla., in September, and several technical subjects were discussed. Subjects for future meetings were decided upon in sufficient number to last the society a year. Among these are several of decided interest to mechanical engineers—for example, flow through tubing, use of taper tubing, working pressures, solubility of gas in oil, corrosion, etc. C. V. Millikan, of the Amerada Petroleum Corporation, told of conditions a few years ago when oil companies jealously guarded all information, and pointed to the great scientific progress made by the industry since the modern idea of exchanging information came into being. (*National Petroleum News*, vol. 119, no. 38, Sept. 21, 1927, p. 343, *g*)

The Liljenroth Process of Phosphorus Manufacture

REFERENCE was made in a previous issue of MECHANICAL ENGINEERING (vol. 49, no. 4, April, 1927, pp. 371–372) to the phosphorus-manufacturing plant at Piesteritz, Germany, working in connection with a plant for the manufacture of a combined phosphorus-nitrogen fertilizer. It is known now that the process employed there is the Liljenroth process. The basis of it depends on the collection of the phosphorus evolved from a mixture of phosphate rock, silica, and coke which is treated in an electric furnace and subsequently oxidized with steam in the presence of a catalyst. The phosphorus pentoxide is converted into phosphoric acid and the hydrogen which is obtained as a by-product is used to produce synthetic ammonia which, in turn, is absorbed by the phosphoric acid and converted into diammonium phosphate. The practicability of the volatilization process has been previously established in a small plant at Niagara Falls. It has been found since, however, that the complete collection of phosphorus requires an elaborate condensing system and that unless special precautions are taken there is very great chance for the "poisoning" of most catalysts. ("Poisoning" of catalysts means their being rendered inactive under the action of certain materials.) The German technicians have apparently found means of circumventing these difficulties, but what these means are has not been made public. (*Chemical Age*, vol. 17, no. 428, Sept. 10, 1927, pp. 232, *g*)

WELDING

Spot Welding of Dissimilar Metals

THE author describes methods employed in the welding of certain ferrous and non-ferrous metals and alloys where the two pieces are dissimilar. Combinations of metals dissimilar in heat and electric conductivity are best welded by the use of two dissimilar electrodes, such as one of copper and one of a copper-tungsten alloy of high tungsten content. Combinations like copper with galvanized iron or copper with nichrome may be welded by using a copper electrode next to the nichrome and an electrode of an alloy rich in tungsten content next to the copper. It is stated among other things that a wide choice of electrode material is available, ranging from pure copper of high conductivity through the copper-tungsten alloy series in which the resistance increases with the tungsten content to pure tungsten which has a still higher resistance. Pure tungsten is seldom used, however, except in cases where two pieces of metal of very high heat conductivity are to be welded.

Like metals and combinations of dissimilar metals which are successfully spot welded may also be line welded by the use of the same combination of welding wheels as is used for spot welding electrodes on the same metal. In line welding it is usually desirable to use an interrupter in the primary circuit of the welding machine, which gives, in effect, a series of overlapping spot welds. This makes possible the use of a much higher welding current without danger of burning through the metals being welded if a thin spot or other inperfection should be encountered.

In making the welding test, material from 1/32 to 1/4 in. thick was cut into strips 1 in. wide. The welds were made in a row along the center line of the strip. Tests were made by pulling the strips apart. If the pieces pulled apart without making a hole in either, it was considered as no weld; but when the welds pulled a hole through either strip, the weld was considered as strong as the weaker material, and therefore successful. (R. T. Gillette, Manager's Staff, Schenectady Works, General Electric Co., in *General Electric Review*, vol. 30, no. 9, Sept., 1927, pp. 443–445, *dp*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Code on Instruments and Apparatus

Preliminary Draft of Chapter 2, Dealing with Pressure Measurement: Part I—Barometers

THE Main Committee on Power Test Codes takes pleasure in presenting to the members of the Society for criticism and comment, Part 1 of Chapter 2 of the Code on Instruments and Apparatus, dealing with Barometers, Pressure Measurement. The Individual Committee which developed this draft consists of Messrs. C. F. Hirshfeld, Chairman, W. A. Carter, Secretary, C. M. Allen, E. G. Bailey, L. J. Briggs, J. D. Davis, R. E. Dillon, F. M. Farmer, J. B. Grumbein, O. Monnett, S. A. Moss, R. J. S. Pigott, E. B. Ricketts, and S. W. Sparrow.

Code No. 19 on Instruments and Apparatus will consist of twenty-one chapters dealing with the following subjects: (1) General Considerations,[1] (2) Pressure Measurement (7 sections), (3) Temperature Measurement[2] (11 sections), (4) Head Measurement, (5) Quantity of Material, (6) Electrical Measurements, (7) Mechanical Power, (8) Indicated Horsepower, (9) Heat of Combustion, (10) Chemical Composition, (11) Quality of Steam, (12) Time, (13) Speed Measurement, (14) Mechanical Measurements, (15) Surface Area, (16) Density, (17) Viscosity, (18) Humidity, (19) Concentration of Dilute Solutions, (20) Smoke, (21) Condenser Leakage Tests.[3]

The Individual Committee, the Main Committee, and the Society will welcome suggestions for corrections or additions to this draft from those who are especially interested in this subject. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

General Considerations

1 *Pressure Determinations.* Barometers are instruments used to measure the pressure of the atmosphere, such pressure being commonly called the *barometric pressure*. This barometric pressure, frequently referred to in the Codes, is determined only after the barometer reading has been corrected for instrumental errors, for gravity, and for temperature (see Pars. 5 to 8).

2 *Gage-Pressure Readings* are given by usual pressure-measuring instruments, such as U-tubes or Bourdon pressure gages. Corrections for calibration errors and for temperature must likewise be applied to the actual gage readings in order to determine the *gage pressure* referred to in the Codes. Such corrected readings indicate the true pressure in the set-up over and above the pressure of the atmosphere.

3 *The Barometric Pressure* plus the *gage pressure* is the *absolute pressure*, determinations of which are required in working up results in many portions of the Codes.

4 For cases where a measured pressure is below atmospheric, the pressure indicated by the corrected reading of a U-tube or a vacuum gage is called *vacuum*, or is expressed with a minus sign. The absolute pressure in such cases is the difference between the barometric pressure and the vacuum.

5 *Correction and Reduction of Mercurial-Barometer and Mercury-Column Readings* (see Pars. 56–59 and Part 6). The readings of barometers and other mercury columns are customarily given in "Inches of Mercury" ("Hg). The height of any mercury column must always be corrected to the value which would be obtained if the mercury column were at 32 deg. fahr. Data for making this correction are given in Part 6 of this chapter, Table 1. However, uncorrected readings may be used in exceptional cases, as specified in Par. 14, Part 6, and line 3, Table 6, Part 6 of this chapter.

6 The height of any mercurial barometer or other mercury column is, of course, to be measured by a scale reading standard inches. Correction for the temperature of the scale is small and therefore is not always necessary in engineering work. The Weather Bureau tables, referred to later, are precise and include a correction for temperature of mercurial-barometer scales.

7 There is always a barometer calibration correction, which is explained in Pars. 60–70.

8 A barometer reading often must be reduced to that value which it would have if taken at a stated elevation, and such reduction is to be made in accordance with Pars. 46, 47, and 48, and Part 6 of this chapter, Table 2. A gravity correction must be made for precise work as outlined in Part 6, Table 3, but is not usually necessary in engineering work.

9 The reading of the barometer is sometimes given to the nearest thousandth of an inch. However, the nearest hundredth will do for usual engineering purposes.

10 For pressures above atmospheric, the reading of the barometer is to be reduced to lb. per sq. in. before adding to the gage-pressure reading expressed in lb. per sq. in., by multiplying the corrected barometer reading in inches of mercury by 0.4912. In cases where absolute pressures less than atmospheric are given in lb. per sq. in., the same factor must be used. In many cases, however, pressures less than atmospheric are given in inches of mercury vacuum. In such cases the vacuum is usually indicated by a mercury column, and care must always be taken to correct its reading for temperature, according to the same rules as given in Part 6, Table 1, for the correction of a barometer reading, before subtracting from the barometric pressure to obtain the absolute pressure. Absolute pressures in inches of mercury shall always be understood to be corrected to 32 deg. fahr.

11 *Methods of Determining Barometric Pressures.* Barometric pressures may be determined either by using a barometer installed in the vicinity of the place of test (always making calibrations by reference to the Weather Bureau or a weather map, as indicated in Pars. 24–29 or 30–32 and 60–70), or by obtaining the readings direct from the nearest Weather Bureau as explained in Pars. 24–29, or by interpolating on a Weather Bureau map as explained in Pars. 30–32.

12 For rough work, absolute pressures greater than atmospheric may be determined without a barometer, by using the table of Average Atmospheric Pressures at Various Elevations, Part 6, Table 4, in conjunction with the gage-pressure readings. For pressures below atmospheric, barometric readings shall always be used.

13 Those who have a plant barometer, or who use a barometer to any extent, should obtain a copy of Weather Bureau Circular F, on "Barometers." See Par. 2, Part 6 of this chapter. See also Circular 46, Bureau of Standards, which deals with the calibration and testing of mercurial and aneroid barometers. A great deal of the data recorded herein has been obtained from these circulars and from officials of the Weather Bureau and the Bureau of Standards.

Description of Instruments

14 A—*Mercurial Barometer.* This is the type of barometer generally used and always recommended. Such a barometer used under this Code shall have the inner bore of the glass tube no less than 0.25 in. in diameter. Fig. 1 is an illustration of the Fortin type, as used by the U. S. Weather Bureau. It consists of a glass tube somewhat more than 30 in. long, closed at one end and inverted over a small cistern. The cistern and part of the glass tube are filled with pure mercury. Above the mercury in the glass tube is a high vacuum, giving essentially zero absolute pressure on top of the column. The atmospheric pressure depresses the mercury in the cistern, so that the column of mercury in the glass tube measured above the level in the cistern exactly balances the atmospheric pressure. The exact height of the top of the mercury column is read by means of a scale fastened to a metal tube which surrounds the glass tube. There is a sliding vernier so that precise readings may be obtained. A thermometer is always attached to give the temperature of the column.

15 Fig. 2 shows a barometer of the Kew type with variable zero level which is corrected for in the scale graduation. Fig. 3 shows a barometer of the siphon type.

[1] This chapter was published in the February, 1923, issue of Mechanical Engineering.

[2] Part 1, General, of Chapter 3 was published in the December, 1925, issue of Mechanical Engineering.

Part 6, Glass Thermometers, of Chapter 3 was published in the April and May, 1926, issues of Mechanical Engineering.

[3] This chapter was published in the November, 1925, issue of Mechanical Engineering.

16 B—*Aneroid Barometer.* This type of instrument is more easily portable than the mercurial barometer, and is used only for this reason, being often less accurate. However, if the instrument is marked "compensated" for temperature changes, and if a proper calibration is made by comparison with Weather Bureau instruments, as described in Pars. 60–70, its use is permissible in cases where accuracy in determination of barometric pressure is not of primary importance. Fig. 4 is an illustration.

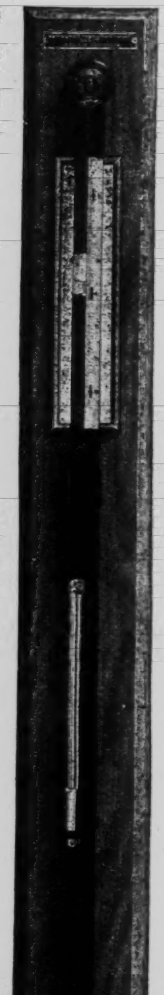


FIG. 1 MERCURIAL BAROMETER (FORTIN TYPE)

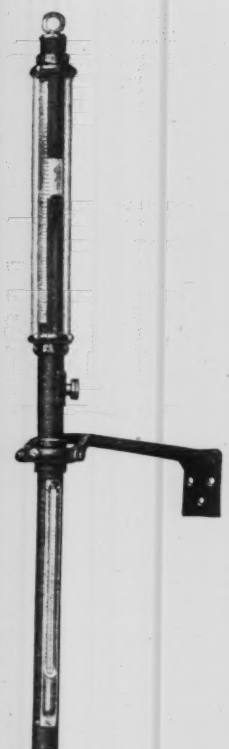


FIG. 2 MERCURIAL BAROMETER (KEW TYPE)

FIG. 3 MERCURIAL BAROMETER (SIPHON TYPE)

17 The aneroid barometer comprises an exhausted chamber, the ends of which are corrugated diaphragms. Atmospheric pressure on the diaphragms is balanced by a stiff spring. The deflection of the diaphragms against the force of the spring is transmitted to a pointer which gives the reading. Sometimes there is appreciable hysteresis. The scale is graduated to read inches or millimeters of mercury, and the reading is that which would be given by a mercurial barometer after correction for temperature and gravity.

18 C—*Recording Barometer or Barograph.* This is an aneroid barometer which actuates a pen moving over a recording drum rotated by a clockwork. Fig. 5 is an illustration.

19 It is subject to all of the inaccuracies of the aneroid barometer plus those due to the pen mechanism and pen friction. Accurate instruments of this type are probably available, but the average instrument is open to suspicion. As this instrument is seldom used in engineering work, directions for use and calibration are not given here.

20 Use of this instrument is permissible only in cases where accuracy in barometric pressure is not of primary importance, and where all parties have investigated the instrument in question, and agreed to its use. Calibration must always be made with particular attention to hysteresis.

21 This instrument is sometimes used to show variation of barometric pressure during a test, often in conjunction with good barometric readings obtained by one of the approved methods given in other paragraphs. In such cases attention must be given to hysteresis.

22 D—*Barometric Pressure Obtained from Weather Bureau Information.* The United States Weather Bureau is of course greatly dependent upon a knowledge of the barometric pressure, and has an excellent system for keeping a record of it. The Weather Bureau officials are always very courteous in supplying engineers with information. In many cases this information may be obtained from the nearest station directly by telephone. In other cases, correspondence may be necessary. There also may be used the published readings of pressure on the daily weather maps.

23 Information from the Weather Bureau, either direct as explained in Pars. 24–29, or from the weather maps as explained in Pars. 30–32, shall always be used to calibrate a barometer. Such information may also be used to give the barometric pressure during a test when a good barometer cannot be installed for the purpose.

OBTAINING BAROMETRIC PRESSURE FROM A WEATHER BUREAU STATION

24 *Weather Bureau Barometer System.* There are U. S. Weather Bureau stations in all of the cities appearing on the daily weather maps. At each of these stations the barometer is read at 8 a.m. *Eastern Standard Time*, which is "75th Meridian Time." This gives a time in the various time zones as follows:

8 a.m. Eastern Standard Time
7 a.m. Central Standard Time
6 a.m. Mountain Standard Time
5 a.m. Pacific Standard Time

Note that Standard and not Daylight Saving time is used.

At many of the stations, the barometer also is read regularly at 8 p.m. Eastern Standard Time. Hence, when a plant barometer is read for calibration purposes, it should preferably be read at 8 a.m. E.S.T. as in the above table, or else at 8 p.m. E.S.T. if it is known that a nearby Weather Bureau station also reads at this time.

Many stations have barographs operating continuously. The daily weather map is also filed in all of the Weather Bureau stations.

25 *Station Pressure.* The reading at a Weather Bureau station, corrected for temperature, gravity, and the calibration constant of the station barometer is called the "Station Pressure" and this is the value which will ordinarily be asked of the Weather Bureau observer.

For places within about 20 miles of the Weather Bureau station, this "Station Pressure" is to be used with only the elevation correction of the next paragraph.

26 In most cases there must be obtained from the Weather Bureau observer the "Station Level" or station elevation, and the atmospheric temperature. With a knowledge of the "Station Level" and the elevation of the point for which the barometric pressure is desired, corrections for differences of elevation can be made, as indicated in Par. 48 and in Part 6 of this chapter, Table 2.

27 *Sea-Level Pressure.* In order to compare barometric readings at different places, and to make weather maps, etc. the "Station Pressure" is reduced by the Weather Bureau to "Sea-Level Pressure" in accordance with tables similar to Table 2, Part 6 of this chapter.

28 In determining barometric pressure at a distance from a

station, or at a period between the regular readings, the assistance of the Weather Bureau observer must be asked. From the sea-level pressure at several nearby stations, weather maps, barographs, and other data which are on file, information can be obtained which will make possible an estimate of the barometric pressure, at any place, either for any particular time, or as an average between two given times.

29 It must of course be known whether or not such an interpolated result, thus obtained, indicates sea-level pressure. If it does, the pressure must be reduced, as described in Part 6 of this chapter, Table 2, to a value corresponding to the actual elevation. It is to be noted that corrections based upon the difference in elevation of the two stations are more accurate than those based upon values reduced to sea level.

FIG. 4 ANEROID BAROMETER

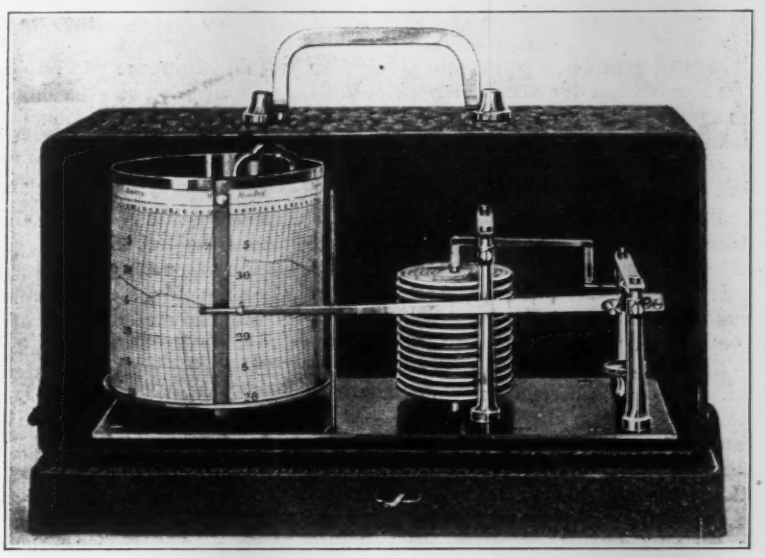


FIG. 5 BAROGRAPH

OBTAINING BAROMETRIC PRESSURE FROM DAILY WEATHER MAPS

30 *Weather-Map System.* There are filed daily at all Weather Bureau stations, and in many post offices and other public places, maps showing a set of "isobars" or lines of equal barometric pressure, and "isotherms" or lines of equal temperature. These are for 8 a.m. Eastern Standard Time. Independent editions of the map are published at the principal Weather Bureau stations, such as New York, Boston, Chicago, San Francisco, etc., and copies for given days should be secured by application to the *nearest* such office.

31 *Interpolation on Weather Maps.* The location, at which a determination of barometric pressure is desired, should be indicated approximately, by a dot on the weather map, and the barometric pressure estimated by interpolation between the values on the adjacent isobars. There are isobars for each tenth of an inch, so that the interpolation will give the barometric pressure to one one-hundredth of an inch. If a determination of barometric pressure is needed for a time other than 8 a.m. Eastern Standard Time, the process described above must be carried through twice: first, with the weather map corresponding to the nearest time previous to the desired time, and second, with the map corresponding to the nearest later time. This determines the barometric pressure for the place in question at 8 a.m. on two successive days. The barometric pressure at the time in question is then to be found by proportional interpolation. Of course, this cannot be done accurately if there has been any violent change such as accompanies a storm or high wind. For very accurate work, the daily swing, or diurnal fluctuation, also needs to be taken into account. Data are given in the Annual Report, Chief of Weather Bureau, 1900, Part 2.

32 *Correction for Elevation.* The above process gives a value reduced to sea level, and it must be corrected to the value corresponding to the actual elevation, as indicated in Part 6, Table 2.

RANGE AND ACCURACY OF BAROMETERS

33 Mercurial or aneroid barometers usually have a range of from 25 or 26 to 32 inches of mercury. Special barometers for use in mountainous regions begin at 15 in. or 20 in. The accuracy required by different cases is given in Part 6, Pars. 3 and 4, and the accuracy obtainable by the various methods of determining barometric pressure is given below.

34 A—*Mercurial Barometers.* Mercurial barometers are usually supplied with verniers which give readings to 0.001 in. However, extraordinary precautions are required to give accuracy to this amount. A good mercurial barometer with the inner bore no less than 0.25 in.; as is obligatory under this Code, carefully maintained and carefully calibrated will give results accurate to about 0.002 in. or 0.01 in.

35 It is common to read and correct mercurial barometers to 0.001 in. However, for many engineering purposes, readings and corrections to 0.01 in. are amply accurate.

36 It is not unusual to find that the calibration correction of a mercurial barometer is a few tenths of an inch. Hence a plant barometer can never be trusted without calibration.

37 If the calibration correction of a mercurial barometer comes at 0.3 in. or more, or if the mercury or glass are so dirty that reading is difficult, or if there is any other obvious trouble, the barometer must be sent to an instrument shop. See Circular F, referred to in Par. 2, Part 6, for "Transportation Instructions."

38 B—*Aneroid Barometers.* Aneroid barometers have scales reading to 0.02 in. to 0.05 in. and can usually be read to 0.01 in. A good aneroid barometer with temperature compensation, carefully handled and carefully calibrated, will give results accurate to about 0.01 in. to 0.10 in. Poor instruments or poor handling may give much greater errors.

39 C—*Recording Barometers.* A good instrument with temperature compensation and small hysteresis, carefully handled and carefully calibrated, will give results accurate to about 0.10 in. Poor instruments or poor conditions may give much greater errors.

40 D—*Barometric Pressure Obtained from Weather Bureau Information.* Barometric pressure obtained by telephone or correspondence for an exact time, and carefully corrected for difference in elevation and distance, will give results accurate to a hundredth of an inch. Uncertainties as to difference in elevation, time, or distance may make errors of a tenth of an inch or more.

41 Barometric pressure obtained from daily weather maps, with good elevation corrections, will give results accurate to about a tenth of an inch with constant weather conditions, and greater errors with varying conditions.

INSTALLATION OF BAROMETERS

42 The observer must verify the following matters: (*a*) the barometer must be installed so as to be free from vibration, air

currents and violent temperature changes; (*b*) it must be in a good light, but not directly exposed to the sun, and not heated by an electric lamp in proximity; (*c*) a mercurial barometer must be hanging freely so as to insure the vertical position of the column; (*d*) there must be a small vent, so that atmospheric pressure reaches the interior of the cistern of a mercury barometer.

43 It is to be noted that blowers supplying air to boilers, turbo-generators, etc. create appreciable pressure differences around a plant, and, if these are present, the barometer must be located close to the condenser U-tubes with which it is concerned. For accurate work, the effect of the change of pressure of the air with elevation must either be eliminated, by having the barometer and U-tubes on the same level as the apparatus in test, or else allowed for as indicated in Part 6 of this chapter, Table 2.

44 A mercurial barometer is not a portable instrument so that it should be installed in a permanent place. An aneroid barometer may be moved, but for accurate work this should be avoided as much as possible, and the readings should be taken in the same location and position as when calibrated.

Precautions in Reading Barometers

45 *Time of Reading.* In usual cases, the barometer shall be read three times for a test: before, after, and once during the period the test is in progress. If less accuracy is required, the barometer may be read immediately before or after a test. The time of reading shall be recorded. For long or precise tests the barometer shall be read at intervals during the test.

46 *Elevation.* The elevation of the barometer must be considered. There is a correction of about 0.01 in. for each ten feet variation of elevation due to a decrease of atmospheric pressure with an increase in elevation. See Part 6, Table 2.

47 If the necessary degree of accuracy, or the difference in elevation warrants, there must be recorded the difference in elevation between the center line of the apparatus under test, and the barometer cistern level. For extreme accuracy, there is also the correction for the elevation difference of mercury U-tubes as indicated in Part 6 of this chapter, Table 2.

48 In the case of a barometer being read for calibration by comparison with Weather Bureau readings, there must be found (to the requisite degree of accuracy) the elevation either above sea level, or with respect to the elevation of the nearest Weather Bureau station. The standard of reference to be used is that of the Weather Bureau, which is the "Mean Sea Level," as defined by the Coast and Geodetic Survey.

49 *Reading the Mercurial Barometer.* The thumbscrew at the bottom of the cistern must be adjusted so that the top of the mercury just touches the ivory point, and then the slider, carrying the vernier, must be adjusted to the extreme top of the mercury-column meniscus.

50 Both of these adjustments are best made by placing a piece of white paper, or the like, behind the barometer, and making the adjustment so that the thread of white above the mercury first has an appreciable width and is decreased until it just disappears. The ivory point must not make a dimple in the cistern mercury. If the mercury in the cistern is bright enough, the ivory point and its image may be seen to just coincide. In making either adjustment, if the screw has been turned too far, go back enough to show a visible white space, and again start decreasing this space until it disappears. The eye of the observer, must, of course, always be on the level of the mercury being observed.

51 The tube and cistern must be tapped lightly while making the adjustments and taking the reading.

52 The reading of the vernier must then be found, and recorded. Care must be taken to record the correct decimal corresponding to the last vernier division. This gives the *Uncorrected Barometric Pressure.* For accurate work, reset the cistern level and take a check reading.

53 The temperature of the column must next be recorded.

54 *Résumé of Reading the Mercurial Barometer.*

(*a*) Note that barometer is properly installed as outlined in Pars. 42 to 44 inclusive.

(*b*) Adjust cistern level as outlined in Pars. 49 to 51, inclusive.

(*c*) Adjust vernier and record reading, as "Uncorrected Barometric Pressure" as outlined in Pars. 49 to 52, inclusive.

(*d*) For accurate work, readjust cistern level, and record a second reading as outlined in Par. 52.

(*e*) Record temperature and time.

(*f*) For accurate work, record difference in elevation between barometer cistern and center line of apparatus, or for calibration readings, record elevation as outined in Pars. 46 to 48, inclusive. See sample reading, correction, and reduction, Par. 59.

55 *Reading the Aneroid Barometer.* The instrument should be tapped lightly while taking the reading. The eye must be held directly over the needle, to avoid parallax. Interpolation between the graduations must be made by estimation to give the last figure in the reading. The instrument should be read in the same position and preferably in the same location as when calibrated.

Barometric Corrections and Reductions

56 The observed readings of the barometer must be corrected as shown by the sample data in Par. 59 and the data and tables in Part 6 of this chapter. The tables give corrections to 0.01 in., which is sufficiently accurate for usual engineering purposes. It is, of course, permissible to use the tables in Weather Bureau Circular for the Smithsonian Tables (Part 6, Par. 2) which give corrections to 0.001 in.

57 Proper discretion as to the required degree of accuracy must of course be used in reading, calibrating, and correcting the readings, as explained in Part 6, Pars. 3 and 4. For very rough work, the "Uncorrected Barometric Pressure" may be used as indicated in Part 6, Par. 14, and line 3, Table 6.

58 It is to be noted that the Weather Bureau barometer scales have been set by comparison with an absolute standard so that the correction for capillarity is included in the calibration and must not be made separately. Any error in the scale setting is also included in the calibration correction.

59 *Sample of a Mercurial-Barometer Reading, Correction, and Reduction.* Plant: River Works, General Electric Co., West Lynn, Mass., 9 a.m. Daylight-Saving Time, June 22, 1922.

Uncorrected barometric pressure (actual reading)	29.80 in. Hg
Barometer temperature, 75 deg. fahr.	
Temperature correction—Part 6, Table 1	—0.13
Gravity correction—Part 6, Table 3 (only for precise work)	—0.01
Calibration correction (must *always* be made)	—0.01
Barometric pressure (at barometer elevation)	29.65
Level of barometer cistern *below* turbine center line, 16 ft.	
Elevation correction Part 6, Table 2 (only for precise work)	—0.02
Barometric pressure at elevation of turbine center line	29.63
Reduced reading 29.63 × 0.4912 = 14.55 lb. per sq. in. = Absolute barometric pressure at elevation of turbine center line.	

Calibration of Barometers

60 Barometers are to be calibrated by comparison with Weather Bureau readings which have been found in either of the two ways given in Pars. 24 to 32. The accuracy obtainable is given in Pars. 40 and 41. The accuracy of the calibration as made must be greater than is required for the readings as given in Part 6, Pars. 3 and 4.

61 The barometer shall not be moved or disturbed during use or calibration; so that the readings for calibration purposes shall be taken without moving the barometer from the position where the test readings are taken. However, if there are blowers creating a pressure difference, as mentioned in Par. 43, and if these cannot be shut down for the calibration reading, the barometer may be carefully moved to a proper nearby point at the same elevation, for the calibration reading. A mercurial barometer must never be taken to a Weather Bureau station for calibration. This is sometimes done with an aneroid barometer, but it is better to make simultaneous readings as already explained in Pars. 24 to 32, inclusive, without moving the barometer.

62 *Calibration of Mercurial Barometers.* A regularly installed mercurial barometer should be calibrated at occasional intervals. A calibration of such a regular barometer, or of a special barometer, shall be made during the course of any set of tests made under this Code. The atmospheric pressure can never be accurately known during a test unless a mercurial barometer is installed nearby, which has been calibrated shortly before the test.

63 *Calibration of Aneroid Barometers.* In case an aneroid barometer is used, calibrations shall be made three times during

the course of a set of tests. A comparison should first be made so as to be sure that the aneroid barometer is somewhere near right. Adjustment should be made if necessary. No further adjustment should be attempted during the test, and the barometer should not be moved or disturbed. After waiting several hours a complete calibration should be made. After a set of tests has been completed, another calibration should be made. The average correction determined by these two calibrations should be used. Aneroid barometers must have automatic means of temperature compensation.[4] However at the best the temperature compensation is rather uncertain, and this is one of the principal objections to the aneroid barometer. An aneroid barometer should always be tapped lightly while being read.

64 *Time of Calibration.* A barometer being read for calibration should usually have this done at 8 a.m. Eastern Standard Time, since the main Weather Bureau observations in all parts of the United States are taken at this time, and the weather maps are made for this time. See Par. 24 for further details. However, Weather Bureau readings at many of the stations are also taken at 8 p.m. Eastern Standard Time, so that this time can be used if necessity warrants.

65 Other times can be used in case of extreme necessity, if there are no storms, but such a comparison requires special attention from the Weather Bureau or interpolation between weather maps. In some places, the making of a calibration reading simultaneously with the Weather Bureau readings as described in Par. 24, will require the same early rising that is required of the Weather Bureau observers. There is no good reason for waiving this.

66 *Calibration Correction.* The difference between the reading of a barometer (corrected for temperature and gravity) at a plant where tests are being made, and the reading for the same location as obtained from Weather Bureau information (with the proper corrections for time, distance, and elevation), gives a constant "calibration correction" which must be made to each reading of the barometer.

67 In the case of mercurial barometers the error is usually due to one or more of three causes: an error in the scale, an error in the scale zero, and the presence of air in the glass tube above the mercury. Air or an error in the scale will give a variable error, while an error in the scale zero will give a constant error. However, the reading of the barometer usually varies so little during a period of test, that the error may, for engineering purposes, be taken as a constant error. The calibration correction also includes minor errors of capillarity, alignment of vernier zero, etc.

68 In the case of a good barometer carefully maintained in a plant, the error should not be more than a few hundredths of an inch. However, in many cases the error may be as great as a few tenths of an inch.

69 If a barometer is off more than 0.3 in., if the mercury is so dirty that reading is difficult, or if there is any other obvious difficulty, the barometer should be sent to an instrument shop for correction. See Circular F referred to in Part 6, Par. 2, for "Transportation Instructions."

No plant barometer can ever be trusted without calibration.

70 *Example of Calibration of a Mercurial Barometer.* Made from 8.00 a.m. reading of a Weather Map.

DATA

Plant—River Works, General Electric Co., West Lynn, Mass., 9 a.m. Eastern Daylight Saving Time, June 22, 1922.

Uncorrected barometric pressure	29.800	in. Hg
Check reading	29.801	in. Hg
Temperature	75	deg. fahr.
Height of cistern above floor	3	ft.
Floor elevation above mean sea level as given by plant engineer	16.82	ft.
Latitude	42.8	deg. N

CALIBRATION

Mean uncorrected reading	29.80	in. Hg
Temperature correction—Part 6, Table 1	—0.13	in. Hg
Elevation correction—Part 6, Table 2	0.02	in. Hg
Gravity correction—Part 6, Table 3	—0.01	in. Hg
Corrected reading, reduced to sea level	29.68	in. Hg
Weather map reading, reported by Boston station of U. S. Weather Bureau 8.00 a.m. Eastern Standard Time, June 22, 1922, reduced to sea level	29.67	in. Hg
Calibration correction	—0.01	in. Hg

Exceptional Research Problems

SINCE 1914, when Ambrose Swasey established the Engineering Foundation, the idea of such a national research institution has gained ground steadily and surely. The income from the Foundation in 1915 was $5000. It has now increased to $30,000. Mr. Swasey's several gifts totaled $500,000. Other outstanding gifts to the Foundation have been $50,000 from Henry R. Towne, $50,000 from Edward Dean Adams, and $10,000 from Seeley W. Mudd. Many donations of equipment, materials for research, services, and money have been made in connection with the cooperative projects in which the Foundation has participated. Several wills of living persons are known to contain bequests for the Foundation.

It is pertinent to inquire what advantage for research such an institution as the Engineering Foundation enjoys over individuals and business organizations. In general, the advantages are similar to those which the Rockefeller Foundation possesses in its well-known work of safeguarding health. They are briefly:

The advantage of long views and broad purposes

The advantage of doing things on a large scale

The advantage of easy coöperation with other institutions

The advantage of not having to produce a profit

The advantage of conservation of funds, continuity of service, and unified direction by experienced trustees

The advantage of flexibility of purpose, avoiding frozen funds and restrained policies

The advantage of the prestige of the four founder engineering societies.

Specific instances of the advantages for effective research possessed by the Engineering Foundation are not difficult to set forth. In modern engineering there are numerous problems constantly arising which no individual or no industrial corporation feels justified in attacking. No individual or company may have the time, equipment, or ability to conduct a particularly difficult piece of research. Frequently a company hesitates to take on, single-handed, a problem which a dozen or a hundred companies should contribute to solve but for which no one takes the lead. In such a situation the Engineering Foundation can step forward as a detached, non-commercial party and invite coöperation, which is usually given promptly and willingly.

Sometimes doubts and obscurities of technical procedure exist which are positively harmful, but which no individual or company feels it a duty to clear up. Such conditions arise in modern industry as a consequence of the rapid changes and adjustments always taking place and of the extremely diversified and disjointed nature of America's tremendous engineering undertakings. Leadership out of such predicaments can best be initiated by an agency like Engineering Foundation. It is to the best interest of the country's industries, not to mention the interests of the engineering profession and the public at large, that such a free, unbiased institution exists to act as a clearing house for engineering research.

More detailed examples of the policy and accomplishments of the Engineering Foundation will be given in a later article. In the dozen short years of its history it has been as busy and active as any of its sponsors could wish. There will always be plenty of opportunities for it to exercise its functions, even when its endowment reaches the $5,000,000 that it hopes to attain.

P. B. M.

[4] If the temperature compensation were perfect it would be so at only one pressure. It has as yet not proved feasible to compensate for changes in stiffness or elasticity of the pressure element with changes in temperature.

Engineering and Industrial Standardization

Standardized Plumbing Equipment in Prospect

DIFFICULTIES experienced by the consumer in matching faucets, bath-tub fittings, and other plumbing devices, and in purchasing repair parts for them, may soon be solved, according to an announcement of the American Engineering Standards Committee. The development of such standards and specifications, proposed by The American Society of Mechanical Engineers, will include materials, performance and efficiency of devices, roughing-in dimensions, and other important technical items having direct bearing upon the service and economy afforded the consumer. G. C. Hecker of the American Electric Railway Association was chairman of the special committee which recommended the approval of the formal request for standardization; his committee has suggested that leadership in the project be assigned to The American Society of Mechanical Engineers and the American Society of Sanitary Engineers. The committee appointed to carry on the actual work of standardization will be adequately representative of all the various interests concerned in the standard and will endeavor to carry on the work in such a way as to comply with all established codes, regulations, and ordinances.

It is the intention to begin work on a few of the more simple items which are most in need of standardization—faucets, for example, the washers and other small parts of which are almost impossible to replace, even in supply stores in large cities carrying sizable stocks of spares. Then the work will progress toward more difficult and more technical items.

The committee will work in close coöperation with the Division of Simplified Practice of the Department of Commerce and with national organizations in the plumbing-equipment field, in order that full notice may be taken of standardization work already completed or in progress, and duplication entirely avoided. Persons interested in the subject either as manufacturers or consumers are invited to communicate any suggestions regarding the work, to the Secretary, The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

A Safety Code for Rubber Machinery

THE first of a series of codes intended to cover the mechanical hazards encountered in the rubber industry, namely, a Safety Code for Rubber Mills and Calenders, has just been issued as Bulletin No. 447 of the U. S. Bureau of Labor Statistics, after its approval as "Recommended American Practice" by the American Engineering Standards Committee.

On account of the broad field to be covered, it was decided by the sectional committee to consider in this preliminary issue only the safeguarding of mills and calenders at the point of operation, and this is the limited work that is dealt with in the new rules.

Among the more important provisions of the code are those relating to safety-trip controls and quick-stop facilities, including methods of determining length of travel after operation of the stopping device, and definite requirements as to permissible time before stoppage on individually driven mills, and mills driven in groups. The code is illustrated with diagrams and photographs showing the location of trip controls and the application of devices for determining stopping distance.

The sponsors for the code are the International Association of Industrial Accident Boards and Commissions and the National Safety Council.

Twenty-one organizations, representing six distinct groups of interests, participated in the work of the Sectional Committee. The chairman of the Sectional Committee was J. E. Congdon, Engineering Department, U. S. Rubber Company, New Haven, Conn.

Wrought-Iron and Steel Pipe and Tubing Standardization

THE ever-increasing use of wrought-iron and wrought-steel pipe for industrial and domestic uses, as they are integral parts of many manufacturing processes and form the arteries and veins of modern power plants, heating systems, and piping systems of all kinds, makes it more and more desirable to have nationally recognized standards of dimensions and materials for such pipe and tubing.

A large amount of preliminary work has already been done in this direction by the American Society for Testing Materials, The American Society of Mechanical Engineers, the National Committee on Metals Utilization, and other national organizations, but in order to develop unified nationally recognized standard specifications, all existing standards and specifications will now be thrown into a common pool and a representative sectional committee consisting of official representatives of every important interest concerned will carry on a large program of standardization under the procedure of the American Engineering Standards Committee. The American Society for Testing Materials and The American Society of Mechanical Engineers have been requested to act as leaders in this work, and, if they accept, will have the responsibility of the organization of the Sectional Committee.

The A.E.S.C. Special Committee on this project, headed by William J. Serrill, Assistant to General Manager of the United Gas Improvement Company, Philadelphia, Pa., recommended the following scope for the work:

> Standardization of the design, dimensions, and material of welded wrought-iron pipe, of welded and seamless steel pipe, and of boiler tubing, including pipe and tubing for high temperatures and pressures.

Revision of Refrigeration Code

THE Sectional Committee in charge of the revision of the Safety Code for Mechanical Refrigeration, which has been recently reorganized, held a meeting in New York on August 24.

The code deals with refrigeration equipment classified as to capacity under three divisions, and further divided as to working medium or refrigerant employed. The section of the Code which has given rise to the greatest amount of discussion is that dealing with small machines for household and similar uses. Accordingly a small Sub-Committee was appointed to make a complete redraft of those portions of the Code in which changes were deemed desirable. In this work the Sub-Committee was instructed to give very careful consideration to the regulations on the subject now pending before the Board of Aldermen of the City of New York.

This Safety Code is being developed under the procedure of the American Engineering Standards Committee, with the American Society of Refrigerating Engineers as the sponsor organization. H. D. Edwards is chairman of the Sub-Committee, F. E. Mathews chairman of the Sectional Committee, and R. R. Leonard, secretary.

Electric Welding Apparatus

STANDARDS for Electric Arc and Resistance Welding Apparatus have been submitted to the American Engineering Standards Committee as a basis for national standards on these subjects, by the American Institute of Electrical Engineers.

It is characteristic of such a rapidly developing industry as electric welding that a certain degree of standardization is necessary as a means of further extension into industrial use and as a basis for further technical developments.

As an example of the rapid growth of electric-resistance weld-

ing, a single plant may be cited in which more than two hundred different automotive parts now undergo welding at some point in their production cycle. More than one thousand men are there engaged in spot and butt welding alone, and nearly three and a half-million spot welds are made every day on the different parts. Spot-welding machines have been made practically automatic.

Large buildings have been completely arc-welded, and this process has also been used for practically all joints in many ships, for tanks, rail joints, pipes, and other purposes. However, resistance welding has proved to be the cheapest method of joining metals.

The standards submitted as a base of national uniformity include nomenclature, methods of making dielectric tests, and methods of rating, to be used as a basis of guarantee for the following types of apparatus used in electric resistance welding operations: direct-current generators, motor-generator sets, transformers, resistors, and apparatus for electro-percussion welding. Further, butt, flash, pressure-contact, spot, and seam welding are differentiated.

The proposal of the Institute, which is of importance to several organized industrial groups, including the Association of American Steel Manufacturers and the American Welding Society, has been referred to the Electrical Advisory Committee for study and recommendation to the A.E.S.C.

Ways to Save 90,000 Lives a Year

HOW accidents on the streets and highways, in other public places, on the sea, in the air, at home and throughout industry, which last year caused the deaths of 90,000 men, women, and children in the United States, can be prevented, is pointed out in resolutions adopted by members of the National Safety Council attending the the sixteenth annual safety congress held in Chicago, September 26-30, 1927.

After adopting a set of resolutions dealing with public safety the delegates unanimously approved the following:

WHEREAS, Some twenty-four thousand workers were killed and hundreds of thousands were injured in industry during 1926, causing pain, sorrow, destitution, interruption of orderly processes, slowing up of production and the economic loss of billions imposed upon employers and employees, and

WHEREAS, More than forty-three hundred employers, members of the National Safety Council have demonstrated that most accidents can be prevented through organized prevention work, and

WHEREAS, It has been demonstrated, by members of the National Safety Council, that this achievement is possible in all fields of industrial endeavor, if all employers and employees will realize that accident prevention is a responsibility which should be shouldered by everyone, Therefore, be it

Resolved, That the members of the National Safety Council and others deeply concerned, assembled in Chicago, Illinois, at the Sixteenth Annual Safety Congress, urgently recommend the following:

1 That all employers make a survey of their respective establishments, both large and small, to ascertain the why, where, and how of accidents and accident prevention.

2 That employers keep and analyze their accident records for the purpose of devising ways and means of preventing the recurrence of accidents.

3 That employers safeguard, insofar as possible, all mechanical equipment or revise manufacturing processes so as to eliminate these hazards.

4 That the personnel of all establishments be impressed with their individual need of safety and with the necessity of properly instructing their fellow-workers in safe practices.

5 That employers support efforts being made by community safety councils, the National Safety Council, federal, state, and municipal officials and others, by conducting necessary organized accident-prevention campaigns.

6 That employers encourage the inclusion of safety education in the courses of public, private, and parochial schools and colleges.

7 That more colleges and universities incorporate safety engineering in existing engineering courses.

Resolved, That those assembled at this Sixteenth Annual Safety Congress hereby express their gratitude to the many employers who have been conducting organized accident-prevention plans in their establishments and supporting the public-safety movement designed to protect the public, and acknowledge their indebtedness to the millions of employees and citizens generally and to other organizations, editors of newspapers, trade, technical, and class periodicals and to radio stations, who have so wholeheartedly supported the safety movement.

The National Safety Council is a non-profit-making, non-partisan organization, whose purpose is the promotion of safety, sanitation, and health in the industrial, public, and home life of the American people. It is financed by its members, 4368 corporations, companies, partnerships, public officials, educators, organizations, and individuals interested in the conservation of lives and limbs and property, who pay yearly dues to the organization. It is the parent body of some sixty affiliated community safety councils scattered throughout the nation. Its officers and 1000 committeemen serve without financial compensation, meeting regularly to determine its policies and program. The organization serves as a national clearing house of accident prevention information, maintaining its headquarters at 108 E. Ohio St., Chicago, where a staff of more than 78 employees devote all of their time to safety work.

The first safety congress was held at Milwaukee, in 1912, and a formal organization meeting was held in New York City in 1913, when the body was originally started as the National Council for Industrial Safety, a name which was changed inasmuch as the scope of the institute broadened to include safety on the streets and highways, in other public places, at home, on the sea, and in the air.

The first president was Robert W. Campbell, attorney for the Illinois Steel Company, a son-in-law of the late Judge E. H. Gary, who was one of the early safety leaders.

The first secretary was William H. Cameron, who is still with the organization, now serving as managing director. It was Mr. Cameron who opened an office with only a handful of members and a few hundred dollars in cash. Last year the council spent more than $600,000 in its perpetual safety campaign and its affiliated units expended a similar amount.

The first congress held in Chicago was in 1914.

It is the contention of the Council that practically all accidents, irrespective of where they occur, can be prevented through intelligent, organized safety work.

Industrial Bodies Join the American Engineering Standards Committee

THE Portland Cement Association and the American Gear Manufacturers' Association have become member bodies of the American Engineering Standards Committee with direct representation on the Main and Executive Committees.

The Portland Cement Association was organized in 1902. It now maintains 31 district offices covering the United States and British Columbia. The Association is spending a large amount annually in its research and standardization activities. F. W. Kelley, President of the North American Cement Association, represents the Association as a member of the A.E.S.C. Executive Committee.

The American Gear Manufacturers' Association was organized in 1917 and now consists of 94 member companies. Since its organization it has been active in standardization work. It has adopted five association standards and 33 recommended practices. Geo. L. Markland, Jr., Chairman of the Board of the Philadelphia Gear Works, represents the Association on the A.E.S.C., with S. L. Nicholson as alternate.

Face-to-Face Dimensions of Ferrous Flanged Valves

AT ITS meeting on October 13, the A.E.S.C. accepted the report of one of its Special Committees which approved the suggestion of the A.S.M.E. that the face-to-face dimensions of ferrous flanged valves be undertaken. The types of valves which are to be included are ferrous gate, globe, angle, and check valves having flange connecting ends and W.S.R. ratings of both 125 and 250 lb. per sq. in.

It is also agreed that the work will be given to the existing Sectional Committee on the Standardization of Pipe Flanges and Fittings, for the reason that it is a natural extension of its present scope, and for the further reason that within its personnel are included representatives of all the groups which are concerned with the standardization of these types of valves.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK,
Aeronautic Division
H. W. BROOKS,
Fuels Division
R. L. DAUGHERTY,
Hydraulic Division
W. F. DIXON,
Machine-Shop Practice Division
CHARLES W. BEESE,
Management Division
G. E. HAGEMANN,
Materials Handling Division
J. L. WALSH,
National Defense Division
L. H. MORRISON,
Oil and Gas Power Division
W. R. ECKERT,
Petroleum Division
F. M. GIBSON and W. M. KEENAN,
Power Division
WINFIELD S. HUSON,
Printing Machinery Division
MARION B. RICHARDSON,
Railroad Division
JAMES W. COX, JR.,
Textile Division
WM. BRAID WHITE,
Wood Industries Division

Railroad

Superheated Steam for Locomotive Auxiliaries

R-13 To what extent is superheated steam supplied to locomotive auxiliaries, and is there any real economy to be obtained through such practice?

A very large number of locomotives built within the last two or three years have been arranged so as to use superheated steam for the auxiliaries which consume the largest quantities. This list of auxiliaries would include the blower, air pump, feed pump, headlight dynamo, stoker engine, booster engine, and whistle. These auxiliaries, because of their relative small size and the conditions under which it is necessary to operate them, are relatively wasteful in the use of steam, and the economies by using superheated steam are therefore on a percentage basis, even higher than those obtained from the main-engine cylinders. There is a marked tendency toward the increasing use of superheated steam for locomotive auxiliaries. (Unsigned contribution.)

Textile

Pumps

T-11 For what purposes are pumps employed in the textile industry and what types are most suitable?

Pumps are employed in textile mills for the water supply, for handling process liquors, for fire protection, etc. In the writer's opinion, the centrifugal type predominates, except for fire protection, where the so-called steam-driven Underwriters' pump is usually preferred. (A. R. Jealous, Assistant Works Manager, The Clark Thread Co., Newark, N. J.)

For power-plant purposes, that is, oil pumps for fuel oil, and feedwater pumps, steam or centrifugal types are used. Dye houses use centrifugals to pump liquor and dyestuffs to tanks. Steam or centrifugal pumps are used for returning hot condensate to the power house. Dyeing machines are equipped with circulating pumps. Sump pumps are provided for sewage disposal. Liquor pumps of the centrifugal type are used for soap making, dye mixing, etc. (Henry M. Burke, Plant Engineer, Mount Hope Finishing Co., North Dighton, Mass.)

Wood Industries

Holding Power of Wood Screws

WI-2 Is there any information on the holding power of wood screws later than that given in Marks' Mechanical Engineers' Handbook, Third Edition?

Technologic Paper of the U. S. Bureau of Standards, No. 319, by I. J. Fairchild, July 17, 1926, describes a series of tests by the Bureau to determine the holding power of wood screws.

Seven species of wood were used: cypress, maple, oak, North Carolina pine, Georgia pine, poplar, and sycamore. Over 10,000 steel screws in sizes 1/4 in. to 5 in. were used, being inserted three-fourths their length in both the side and end grain of the various pieces, and the results appear in tabular form in the paper.

The results tabulated below show the average load required to withdraw the screws from the side grain, as recorded by the testing machines:

AVERAGE LOADS (EXPRESSED IN POUNDS) REQUIRED TO WITHDRAW STANDARD STEEL SCREWS FROM THE SIDE GRAIN OF DESIGNATED WOODS

Number and length of screws	Cypress	Poplar	Sycamore	N. C. pine	Georgia pine	White oak	Maple
Average for Sizes 0 to 4—1/4 in.	17	17	31	18	61	55	80
Ratio	1.00	1.00	1.72	1.06	3.59	3.24	4.71
Average for Sizes 1 to 10—1/2 in.	74	103	163	127	199	195	277
Ratio	1.00	1.39	2.20	1.72	2.69	2.64	3.74
Average for Sizes 2 to 14—3/4 in.	156	215	305	266	395	418	569
Ratio	1.00	1.38	1.96	1.71	2.53	2.68	3.65
Average for Sizes 3 to 16—1 in.	237	322	461	427	588	702	875
Ratio	1.00	1.36	1.95	1.83	2.49	2.96	3.69
Average for Sizes 4 to 20—1 1/2 in.	409	569	761	755	973	1,202	1,350
Ratio	1.00	1.39	1.86	1.85	2.38	2.94	3.30
Average for Sizes 6 to 20—2 in.	610	836	1,045	1,131	1,445	1,765	1,888
Ratio	1.00	1.37	1.71	1.85	2.37	2.89	3.10
Average for Sizes 6 to 20—2 1/2 in.	715	1,039	1,218	1,408	1,712	2,037	2,172
Ratio	1.00	1.45	1.70	1.97	2.39	2.85	3.04
Average for Sizes 8 to 24—3 in.	950	1,331	1,634	2,012	2,276	2,546	2,866
Ratio	1.00	1.40	1.72	2.22	2.40	2.68	3.02
Average for Sizes 12 to 24—4 in.	1,425	1,770	2,399	3,185	3,233	3,517	3,914
Ratio	1.00	1.24	1.68	2.24	2.27	2.47	2.75
Average for Sizes 14 to 24—5 in.	1,873	2,383	2,900	3,436	3,670	3,800	3,882
Ratio	1.00	1.27	1.55	1.83	1.96	2.03	2.07

Where splitting can be avoided, the end grain should support about 75 per cent of the safe load computed for the side grain under similar conditions.

The investigation developed some important conclusions of interest to manufacturers of wood products and builders' hardware, and users of wood screws generally. In softwoods the lead hole should be bored about 70 per cent as large as the core or root diameter of the screw; and in hardwoods about 90 per cent as large. A lubricant such as soap may be used where necessary for easy insertion without any great loss of holding power. In selecting a screw, use the smaller diameter and longer length when practicable. In general, a long, slender screw holds better than a short, thick one. For a given length of screw, axially loaded, the holding power increases with the diameter to a certain limit, beyond which it decreases. For a given diameter of screw, the holding power in hardwoods increases with the length and if the screw fails the threads will give way before the wood.

Miscellaneous

Elimination of Dye-House Steam

M-11 What is the latest practice in the elimination of steam from dye houses and similar establishments?

Introduction of outside air (heated as required) near the floor. Exhaust hoods over sources of vapor production with exhaust fans

drawing through heat economizers in the form of dehumidifiers, through which make-up water for the plant is pumped and warmed through condensation of vapor from the passing air. (S. C. Bloom, Consulting Engineer, Chicago, Ill.)

DRAFTING ROOM PRACTICE

M-12 The Sectional Committee on Standards for Drawings and Drafting-Room Practice, sponsored by the A.S.M.E. and the S.P.E.E. under the procedure of the A.E.S.C., will be pleased to have the suggestions of engineers, educators, and others interested in the subject, as to methods best suited to the demands for speed, neatness, and accuracy.

The need of standard methods to be adopted in drafting-room practice has been apparent for a number of years. In compiling standards for drawing and drafting-room practice, the Committee in charge of this work should not outline methods to be followed by the draftsman which might tend to fetter him and thereby do away with the personal or artistic phase of drawing which may be termed "style." The time element will have to be reckoned with in all cases. With this in mind, the draftsman should be able to effect a considerable saving of time if he is allowed a freer range in the style of lettering to be used, a more liberal use of pictorial drawings, and if he is encouraged to use more freehand or technical sketches. It should be recognized that the principal factors in drawing are accuracy, speed (the time element), neatness, and style.

The factors mentioned above have their limitations. One may depend upon the other. Accuracy cannot be carried to a higher degree than the accuracy of the data available. Also, it is not good practice to carry refinements of collecting data and of computations to a higher degree of accuracy than the particular project in hand will justify. A draftsman is usually working under pressure in order to save time and labor. He should cut corners and increase his capacity as much as practicable. A great deal of time can be saved if the proper slope of letters is used. It is maintained that inclined letters are more rapid of execution than the vertical letters. This is usually true, because handwriting, in the majority of cases, is inclined. Then the question will arise as to the angle a letter should be inclined. In the majority of cases, an individual's handwriting will be inclined 30 deg. from the vertical, but not in all cases by any means. Often the angle is much less than 30 degrees. In many instances, a handwriting may be vertical, or even inclined to the left or "backhand." It has been the writer's observation over a number of years of experience in both the class room and drafting room that if a student or draftsman is permitted, he will eventually choose the angle at which to slope his letters to fit the angle of his handwriting. If he is permitted to make this choice, quite a saving in time is effected. The back writers, however, will invariably practice vertical lettering. Usually, the instructions are to set the inclined letter at approximately $22^1/_2$ deg. from the vertical. It is doubted seriously if the letter which is set at $22^1/_2$ deg. looks any neater, or is any more graceful, than the letter which is set at 30 deg. Nor is the $22^1/_2$-deg. letter to be preferred to the vertical letter. Certainly, in the majority of cases, the 30-deg. letter is more quickly made. If a drafting office is willing to forego uniformity of lettering on all drawings, a saving of time will be accomplished if the draftsman is allowed to slope his lettering to fit his handwriting. In most cases, inclined lettering will be the result, but the slope of the lettering will vary with the individual.

It seems to be common practice to use only orthographic projections in engineering drawing. This is not universally true, however. Pictorial representations may be often employed in adding clearness to a drawing and in the saving of time and labor. Assembly views, if the object is not too complicated, may be put in one of the pictorials to a good advantage. Working drawings of small machine parts and the like can occasionally be made in pictorial with a saving of time and the addition of clearness as a result. The detailing of certain parts which are difficult to read in the orthographic should have an added view in pictorial. The draftsman will find it a great advantage if he is able to make freehand or technical sketches in either orthographic or pictorial. In the use of pictorial sketching, the "fake perspective" (one or two point perspective) is often employed advantageously. Sketches may be used as preliminary drawings, temporary drawings, and are even used at times for unimportant shop drawings. If made on sketching paper, blueprints may be made and the sketches filed away, thus saving the making of a finished drawing.

It is not necessary to dwell on the phase of neatness, the importance of which is well recognized. But there is a lot yet to be said on the subject of style in drawing. Engineering drawing is distinctly a language, a graphical language. There is a style to be developed in drawing just as there is a style written into any literature. Style is indicated by the ease and accuracy with which a drawing may be read. A drawing properly executed will stand out, while other drawings which may contain all the necessary information may be difficult to decipher, and will not inspire confidence. The number of views, the selection and placement of views, the proper use of pictorials, the omission of ambiguous and unnecessary parts of a drawing, good and effective lettering, the size and placement of dimensions, shading where necessary by proper method, the proper use of conventional breaks and cuts, and the contrast of lines are all factors to be employed in developing style.

Engineering drawing is a form of mechanical drawing. It necessitates mechanical action and thought, but should not be carried to the point of shutting out all of the artistic touch and sense. If the draftsman is encompassed with a lot of unnecessary mechanical rules and standards, his work will be truly mechanical and will tend to hamper original thought and personal developments. It may even work out in a way so as to slow up the draftsman and reduce his efficiency. (I. N. Carter, Assistant Professor of Civil Engineering, University of Idaho.)

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

Needless Depreciation Charges

TO THE EDITOR:

In a paper entitled Oil Pipe Line Power and Fuel Problems, read at the meeting of the Mid-Continent Section, A.S.M.E. at Tulsa, April 7, last, Mr. S. P. Young furnishes an enlightening comparison of costs of pumping oil by Diesel engines and by electric power. The author's analysis leads him to conclude that for a temporary gathering station in a flush field it is more economical to use motor drive, but that if the installation is to have a life of more than $3^1/_2$ years, it will pay to use Diesel engines.

The conclusion is sound in principle, if not in amount. In fact, the author's own figures show that a Diesel plant will pay for itself in as short a time as $2^1/_2$ years instead of $3^1/_2$.

The comparative costs are based on Diesel- and electric-driven plants pumping 24,000 bbl. of crude oil per 24 hours at 600 lb. pressure. The data given in the paper may be summarized as follows:

Initial Costs	
Investment in Diesel station	$95,883.11
Investment in electric station	$38,018.15
Extra investment in Diesel station	$57,864.96
Annual Cost of Operating Diesel Station	
Interest and depreciation at 15 per cent	$14,392.47
Machinery maintenance	1,900.00
Cost of fuel	7,798.12
Total of above items	$24,090.59
Annual Cost of Operating Electric Station	
Interest and depreciation at 15 per cent	$ 5,702.73
Machinery maintenance	495.00
Cost of electric power	34,749.00
Total of above items	$40,946.73

From the above figures the author deduces that the difference in annual operating costs in favor of the Diesel station is $16,856.14 ($40,946.73 less $24,090.59). He then divides the extra investment of $57,864.96 by this amount, the quotient being 3.44. He thereupon concludes that in about 3½ years the Diesel plant will catch up and pass economically the electric-motor-driven station.

The error lies in the fact that depreciation was included in the annual operating cost. A depreciation charge is not a cash outlay, but merely a sum shown on the books as a future expense that will be incurred when the plant will have worn out and require replacement. Obviously, if the plant is to be paid for immediately out of the savings in cash outlays, it is wrong to include a depreciation charge in the statement of annual operating costs. By letting the savings pay back the investment, the element of depreciation disappears, as the plant is paid for before it wears out. For instance, if the annual cash savings will pay for an improvement in 3 years, and are so used, it is superfluous to set aside a depreciation fund to pay for it again at some future date, say, 15 years off, when it will have worn out. In other words, the very act of paying for the plant out of the annual savings takes care of the depreciation.

Consequently, in this case, instead of figuring interest and depreciation at 15 per cent, interest alone should be included. Furthermore, the interest is a gradually decreasing amount, because the extra investment is steadily being paid back by operating savings. Thus, if a plant pays for itself in 3 years and the interest is 6 per cent, the average annual interest cost is 4 per cent on the original investment.

Substituting "average interest at 4 per cent" for "interest and depreciation at 15 per cent," the annual costs compare as follows:

Annual outlay for operating Diesel station	$13,533.44
Annual outlay for operating electric station	36,764.73
Annual saving in outlay in favor of Diesel station	$23,231.29

Years to retire increased investment in Diesel station

$$\frac{\$57,864.96}{\$23,231.29} = 2.49$$

Thus in only 2½ years the savings with the Diesel plant will pay back the extra investment.

EDGAR J. KATES.[1]

New York, N. Y.

High-Temperature and High-Pressure Steam Lines

TO THE EDITOR:

The writer recently obtained from the A.S.M.E. reprints of several interesting papers which it has published, and now writes with regard to some apparent omissions in one of them.

In a paper on High-Temperature and High-Pressure Steam Lines, by B. N. Broido,[2] Babcock's formula for the flow of steam is given on p. 1215, also Martin's, the latter being expressed as

$$P = CW^2L/Vd^5$$

On the same page Fritsche's formula is referred to and the author appears to imply (although he does not actually say so) that it is the same as Martin's with the single exception that the coefficient C is different, the value of this coefficient being determined in accordance with the formula given on p. 1218.

It is also stated on p. 1218 that a table for the values of $C \times 10^6$ is given in Marks' Mechanical Engineers' Handbook. However, the writer has before him the 1924 edition of Marks' Handbook and cannot find the table referred to.

Turning now to the discussion on the paper, a worked-out example for the Fritsche formula is given on p. 1238. By a twofold printer's error, $\frac{T}{pw} = \frac{516 + 460}{165 \times 66.6}$ is given as $\frac{T}{p^w} = \frac{516 - 460}{165 \times 66.6}$.

It also would appear (if the worked-out example is correctly stated) that Fritsche's formula is not the same as Martin's, with the sole difference in the value of C, but is widely different, the complete formula being $P = CW^2L/vd$.

In the denominator of Martin's formula, as given in on p. 1215, V represents the weight of the steam on pounds per cubic foot, while d^5 represents the fifth power of the pipe diameter in inches.

In Fritsche's formula, as worked out on p. 1238, v apparently represents the density of the steam in *cubic feet per pound*, while d (without any exponent) appears to be the diameter of the pipe in *feet*.

Owing to the fundamental differences between the Martin (p. 1215) and Fritsche (p. 1238) formulas, notably the pressure drop in the one varying as the fifth power of the diameter of the pipe and in the other directly as the diameter, it has occurred to the writer that perhaps Fritsche's formula, which is not given in its entirety on p. 1218, has been wrongly stated by the discusser, Mr. C. M. Gordon, on p. 1238.

The matter appears sufficiently important to be gone into and the writer would be pleased to learn what corrections or additions, if any, require to be made to pp. 1218 and 1238 of the paper to make matters quite clear.

The writer has no independent records as to Fritsche's formula, apart from an incidental reference in "Marks'" (1924), where on p. 370 a formula of Fritsche's is given which does not apparently bear any resemblance to the formula given on p. 1238 of the paper in question.

EDWARD G. HILLER.[3]

Manchester, England.

TO THE EDITOR:

The writer wishes to answer the questions of Mr. Hiller on the late Mr. Broido's paper. It is his desire to satisfactorily explain the formula comparisons and to supply any data which were omitted from the original paper for the sake of brevity. These omissions were of course based on the assumption that such data were available from the other sources stated.

The usual expression for Martin's formula is:

$$P = \frac{CW^2L}{Vd^5}$$

where P = pressure drop in pounds per square inch
C = coefficient of friction
W = weight of steam flow in pounds per minute
L = length of pipe in feet
V = density of steam in pounds per cubic foot, and
d = diameter of pipe in inches.

The Fritsche formula as expressed in Marks' Mechanical Engineers' Handbook, edition of 1916, page 360, is:

$$p' = \frac{1.07\ cw^2L}{vd}$$

where p' = pressure drop in pounds per square inch
c = coefficient of friction, determined from table on page 359 of Marks' Handbook, 1916 Edition
w = velocity of steam in feet per second
L = length of pipe in feet
v = specific volume of steam in cubic feet per pound, and
d = diameter of pipe in feet.

It was used in this form in the solution of problems in the paper under consideration.

The Martin formula can, however, be changed to the Fritsche form and will then differ from it only in the value of the coefficient of friction.

$$w = \frac{Wv}{60\ \frac{\pi d^2}{4 \times 144}} \qquad W = \frac{\pi d^2 w}{9.6v} = \frac{0.3273\ wd^2}{v}$$

$$V = \frac{1}{v}$$

$$P = C\ \frac{\frac{0.3273^2 w^2 d^4}{v^2}}{d^5\ \frac{1}{v}} \qquad L = \frac{0.10712\ Cw^2L}{vd} \quad \ldots\ldots\ldots\ldots [1]$$

[1] Consulting Engineer. Mem. A.S.M.E.
[2] Trans. A.S.M.E., vol. 44 (1922), pp. 1199–1242.
[3] Chief Engineer and General Manager, the National Boiler and Insurance Co., Ltd.

C for Martin's formula = 0.0003133; substituting this value in [1], gives

$$P = \frac{0.00003355\ w^2L}{vd} = \frac{0.000002796\ w^2L}{vd}$$

where d is in inches and feet, respectively, the latter being the Fritsche form.

Mr. Hiller has made the proper correction in the formula T/pw, where T = absolute temperature of steam in degrees fahrenheit,
p = absolute pressure of steam in pounds per square inch, and
w = velocity of steam in feet per second.

The writer trusts that the above is a satisfactory answer to Mr. Hiller.

C. W. GORDON.[2]

New York, N. Y.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 555 to 562 inclusive, as formulated at the meeting of September 16, 1927, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 555

Inquiry: Is it permissible, under the rules of the Code, to attach heads to the shells of vertical fire-tube miniature boilers by fusion welding when the shells are extended beyond the heads so that the heads are subject to pressure in a longitudinal direction only and the tubes therein are located so close together and to the shell that they are able to carry practically the entire stress imposed upon the head?

Reply: The Code for Miniature Boilers makes definite provision for shells with integral heads and for circumferentially riveted head joints, but Par. M-7 specifically states that autogenous welding may be used in such joints only where the safety of the structure is not dependent upon the strength of the weld. It is the opinion of the Committee that the stress on the heads of fire-tube boilers cannot be considered as fully supported by the expanding and beading of the tubes, as, when overheated, this form of tube attachment loses its supporting power. The heads of such boilers can therefore be considered as fully supported by the tubes independent of the shell only when stay tubes are used with nuts fitted on the ends, or when otherwise stayed in accordance with Par. P-199.

CASE NO. 556

Inquiry: Is it permissible to connect a steam generating unit, constructed in accordance with the requirements of the Code for Miniature Boilers, directly to a cast-iron body vulcanizer by means of a close connection? It is to be noted that the entire apparatus is to be tested hydrostatically to a pressure of 600 lb. per sq. in.; that the working pressure is not to exceed 100 lb. per sq. in.; that the water level is to be maintained within the generator; and that the combination is to be operated as a closed system, without extraction of steam, which makes it necessary that no valve come between the steam generator and the vulcanizer.

[2] Mechanical Engineer, The Superheater Company, Assoc-Mem. A.S.M.E.

Reply: It is of the opinion of the Committee that a vulcanizer so connected should not be considered as a part of the steam boiler and that the Code applies only to the steam generating unit. The combination described should not conflict with the requirements of the Code, as a stop valve between the steam generator and the vulcanizer in a closed system is not required.

CASE NO. 557

Inquiry: With reference to Par. P-192*c*, is it permissible to calculate the efficiency of the ligaments which come in a circumferential line by reference to the metal in the entire circumference or one-half the circumference of the drum, or must the efficiency be calculated by reference to the circumferential pitch of the tube holes?

Reply: It is the opinion of the Committee that the efficiency for the ligaments that come in a circumferential line shall be computed in the same way as those which come in a longitudinal line.

CASE NO. 558

(In the hands of the Committee)

CASE NO. 559

Inquiry: Is it permissible, under the requirement of Par. P-314 of the Code, to discharge the feedwater in a horizontal return-tubular boiler at a point about three-fifths of the length from the rear head, instead of from the front head, where such boilers are gas- or oil-fired and the zone of heating is nearer the rear of the boiler, causing a different condition of circulation than with coal firing?

Reply: It is the opinion of the Committee that the intent of the Code was to discharge the feedwater at about three-fifths of the length of the boiler from either end of the boiler which is subjected to the hottest gases of the furnace. The feed pipe should be carried through the head or shell furthest from the point of discharge of the feedwater.

CASE NO. 560

Inquiry: Is it permissible to attach the markings on miniature boilers by means of a brass etched or stamped plate which will be attached to the shell by riveting, or by a steel plate with an embossed or stamped lettering to be attached by either riveting or welding?

Reply: It has been the intent of the Committee to provide for the marking of miniature boilers along such lines as will conform in general to the corresponding requirement in the Power Boiler Section of the Code, and it is the opinion of the Committee that to mark miniature boilers by use of a name plate, irremovably attached to the shell plate, will conform to the requirement in Par. M-19.

CASE NO. 561

Inquiry: Does Par. U-62 of the Code apply only to cylindrical pressure vessels, or does it apply also to jacketed vessels of any shape such as rectangular, jacketed, staybolted vessels?

Reply: It is the opinion of the Committee that the requirement in Par. U-62 applies to vessels of any form, in which the largest dimension of any cross-section taken at right angles to the longest dimension exceeds 12 in.

CASE NO. 562

Inquiry: Is it permissible, under the requirements of the Code for miniature boilers, for the hydrostatic testing of completed boilers, to subject them to an equivalent pressure of $1^1/_2$ times the working pressure with compressed air instead of water? It is noted that a hydrostatic test is called for in Par. P-329, and the question has arisen as to whether the use of water instead of air was not specified in view of the danger which might ensue in case of rupture of a vessel tested with air.

Reply: The Code specifically calls for a hydrostatic test of every boiler after completion, the use of water being required not only for consideration of safety in case of rupture of the vessel, but also for greater effectiveness in detecting leakage that may require calking or other treatment.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

Charles M. Schwab, *President*
Erik Oberg, *Treasurer* Calvin W. Rice, *Secretary*

PUBLICATION COMMITTEE:
Ralph E. Flanders, *Chairman* K. H. Condit
E. D. Dreyfus W. A. Shoudy
F. V. Larkin

PUBLICATION STAFF:
C. E. Davies, *Managing Editor*
Frederick Lask, *Advertising Manager*

Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . . . printed in its publications (B2, Par. 3).

"The Metropolis"

A MOVING picture under that name and originating in Germany has been shown around the country during the past year. Apart even from its artistic merits it is a remarkable picture, and one of decided interest to the engineer. It shows an organization of production and a social structure as the author expects it to be in some not very distant future—perhaps fifty years hence. The workers have become poorer and the rich richer, until the former live in underground, cavern-like structures while the latter lead a life of supreme luxury. John Masterman is the owner of the city of Metropolis with all its vast accumulation of wealth.

In the conception of the author the men work ten hours a day at a rate of effort so exhaustive that they can barely walk into the huge elevator carrying them to and from the shops. Accidents are the rule rather than the exception. An organized spy system is devised to report every movement of the men. For their religious excercises they have to meet in catacombs. All the machinery is manually controlled.

It is interesting to compare this picture with the actual conditions prevailing in this country and the clearly established trends of modern industry. Instead of working ten hours at a terrific rate which leaves the workman exhausted even at the beginning of the next working day, the day is practically universally reduced to eight hours, and the workman is becoming more and more a machine attendant rather than an actual operator. Industry is recognizing more and more thoroughly that as long as the workman has nothing to do but look at the machine he is making money, but that when he gets busy it means trouble and a loss of earnings. Instead of a colorless life in huge, barrack-like structures underground, the modern American worker owns an automobile which takes him quickly to work and permits him to live in pleasant surroundings, often at a considerable distance from his place of employment. The John Mastermans, super-billionaires, controllers of destiny of whole regions, are becoming more and more obsolete. There are still industrial giants personally controlling great enterprises. The Ford Motor Company and the Weyerhauser lumber interests are examples of this, but they are becoming rarer and rarer, and in the majority of cases the ownership of enterprises is scattered and an earnest effort is made to attract the employees in this direction. Among the larger companies following this policy may be mentioned the United States Steel Corporation and the American Telephone and Telegraph Company.

In the realm of safety likewise enormous progress has already been made, and a greater progress is being achieved as compared with that which prevailed, say, twenty years ago. The number of men killed by boiler explosions has been reduced to a fraction of its former size. In steel mills similar progress has been made, and, for example, the rod mill, which a generation ago was a place of truly great danger, has now become practically completely safe.

The conception pictured in "Metropolis" is not true, and does not represent the real tendencies or the way our industrial future is shaping up under present conditions. It is important to realize, however, that it is only engineering progress and a more enlightened attitude toward relations between labor and capital which have made possible a future so radically different from that shown in this remarkable German screen presentation.

The Oil Situation in the United States

THE oil situation in the United States is becoming a very serious matter, one well worth the attention of the engineering profession. It is also a very complicated matter, involving angles of legal sanctions, economics, engineering, and internal and international politics. Further, the question of national defense is seriously affected. In the past, reserves of oil in the United States have been automatically protected by the generally prevailing state of ignorance as to their location. The oil fields revealing their presence by clear surface indications were discovered and drained long ago. The hidden fields remained hidden until tapped by wildcat wells, which means guesswork. Notwithstanding the intense search for new oil fields in the period between, say, 1910—marking the beginning of the true expansion of the automobile industry—and 1920, the discovery of new fields barely kept pace with the demand for oil. The situation has changed within the last few years and is rapidly reaching the stage where in the near future it will be feasible at a comparatively reasonable expense to plot a map of underground supplies of oil.

Now liquid oil is as good as money in the bank any day of the week. With a knowledge that oil exists in a certain locality, to be reached at a comparatively small cost, it is only some strong restraint that will prevent robber exploitation of underground oil reserves. Experience in the Seminole oil field has shown that it will be impossible to impose such a restraint by agreement, and the only hope lies in a legal sanction. The present law governing oil drilling apparently does not permit this. Queerly enough, practically the same laws apply to underground oil, according to court decisions, as apply to wild game, namely, "He who catches it, has it." There has been considerable demand on the part of representative oil men for state and federal laws, preferably the latter, restricting or governing oil drilling. Apart from the fact that it will be extremely difficult to word such a federal law in a manner not to conflict with state sovereignty on one hand, and to escape the objection of taking property without due process of law on the other, it must not be forgotten that if such a law were passed by Congress, it would certainly be thrown into the courts and would remain inoperative for a number of years until a decision as to its constitutionality had been reached by the United States Supreme Court.

In the meantime, new oil fields are being uncovered and the output of old fields tremendously increased by improved methods of operation. Among the new fields outside of the spectacular Seminole may be mentioned present drillings in eastern Texas and western Florida, both of which bear promise of development.

The prevailing low cost of oil, while apt to keep stockholders of oil companies awake, by no means is an unmixed evil. It has already led to an expansion of the application of the Diesel engine for marine transportation which would have been impossible in the face of a rising curve of prices on fuel oil. Another development of perhaps still greater importance is the growth of household oil heating. Here a very conservative public had to be educated to a new method of operation. The low price of oil has certainly made this possible, and so great is the influence

of the use of oil fuel in the home that the output of the anthracite mines has been seriously affected. Here, by the way, is a chance for mechanical engineering to find some new application for anthracite and thus save an important industrial region of the country from the pall of depression.

The development of the Diesel locomotive for general rail service has not yet apparently reached the intensive stage, but the Diesel-electric locomotive for switching service seems to be finding favor among railroad men, as witnessed by the success of the Ingersoll-Rand type and the entrance of the McIntosh-Seymour Company into the same field.

While the oil situation is unquestionably a serious one, it is as yet by no means certain that it is developing along lines that will ultimately do harm to the country's industries. After all, economic machinery sooner or later takes care of such situations by the operation of the law of supply and demand. Ultimately a stage will have to be reached where prices will be so low as to prevent opening up of new fields not conveniently located with respect to the best markets. This may be a wasteful process of adjustment, but it will produce an adjustment just the same. Furthermore, no one knows yet how great are the underground supplies of oil in this country. There is reason to believe that they are actually much greater than is generally supposed, and through foreign investments United States interests control also vast oil fields in Mexico and Central and South America, have a substantial share in the oil fields of Mosul, and are on the lookout for an entry into the Persian fields and eventually into the rich Russian fields. The oil situation, therefore, is one which should be closely followed by the mechanical engineer, but is probably not yet one concerning which there is any particular cause for alarm.

Gunning for Airplanes

ANTI-AIRCRAFT gunnery occupied the center ring of the ordnance circus at the Aberdeen Proving Ground on October 6, 1927. A combination of clever mechanical and electrical devices for sighting and ranging on the moving targets revealed an accuracy of gunfire that amazed the six thousand spectators who came from all over the country. The occasion was the Ninth Meeting of the Army Ordnance Association. This series of annual gatherings has aroused great public interest in ordnance development, and the attendance has mounted rapidly from year to year. In this year's show the latest types of ordnance material were shown in service, and the large crowd enjoyed to the full the roaring of the big seacoast guns and the popping of the shoulder rifles, the tank attack with infantry, the airplane bombing, the smoke screens, the tractor-driven artillery and the batteries of machine guns, field guns, and mortars firing all types of ammunition.

The offensive power of aircraft has received much attention in the public press. The Ordnance Department has been busy devising defensive measures, which have found their way into the newspapers and the news reels, so the visitors at Aberdeen were keen to see the heralded devices for finding and hitting the attacking planes. In the demonstration, machine guns and coast-defense guns on anti-aircraft mounts were fired against targets towed by airplanes. The first few attacks were on the target at a height of 1500 feet moving about 100 miles per hour, and the weapons were machine guns of 30 and 50 caliber using tracer ammunition and 37-mm. guns. Then the 3-inch guns went into action and the path of the target was dotted with puffs of white smoke as the shrapnel burst. A second plane with a target 2500 yards behind it then appeared as two barely visible specks at 7500 feet, and the 105-mm. guns opened fire. The targets were so small that most spectators could find them only by watching for the puffs of shrapnel burst from the 33-pound projectiles. When the crowd assembled at noon for mess, the cylindrical targets of red canvas, hooped at one end and nearly closed at the other, were spread out on the grass and the holes could be counted, fourteen in one and fifty-seven in another. The final and most spectacular part of the anti-aircraft show occurred after dark, when the giant searchlights were used to find the targets which were attacked with tracer bullets and bursting shrapnel. The day came to a climax when a shell broke the tow line and the target fell slowly earthward.

The demonstration of the new range-finding device was an overwhelming success and the superhuman devices which made it possible justified the time and effort spent on it. This collection of instruments found the target, computed the range, calculated the trajectory of the projectile to reach the target, figured the elapsed time the fuse must burn before exploding the shell, set the gun at the desired elevation, pointed the gun in the direction necessary, set the fuse, and fired the piece. The action was automatic except for the loading of the gun. The range finders kept the target on the cross-wires of the telescope, and the mechanism took care of the rest.

Skeptics in the audience pointed out that attacking planes did not convenience the anti-aircraft defense by keeping a nice straight course at a uniform level and a reasonably low speed. The fact is, however, that anti-aircraft batteries shooting as well as they did at Aberdeen are a protection to be reckoned with up to a height of 7500 feet, and above that bombing accuracy is questionable.

Frank C. Wight

IN THE sudden death of Frank C. Wight, the engineering profession lost a prophet of the younger generation. As editor of *Engineering News-Record* for three years Mr. Wight had revealed himself as a sane spokesman for the best in engineering, and displayed a vision and power that presaged much for the future. While his influence was felt most in the field of civil engineering, his potentiality for service to the entire profession was widely recognized, and the engineers of America are the losers by his departure.

The Schneider Trophy Airplane Race

THIS race was won by Great Britain in a Supermarine S.5 equipped with a Napier geared engine and piloted by Flight Lieut. S. N. Webster, R.A.F. Two other British machines—one a Supermarine with a Napier ungeared, and a Gloster with a geared Napier—have shown excellent speed and performance, the last, however, having come down in the sixth lap after having shown the amazing speed of 289.01 m.p.h. in one of the circuits.

There are two notable facts about this race. In the first place, it illustrates in a striking way the progress made in aviation since the first Schneider Trophy Race at Monaco in 1913, won at a speed of 45.75 m.p.h. In 1925 a Curtiss machine carried off the honors at 232.57 m.p.h., to be exceeded by a Macchi machine in 1926 at 246.496 m.p.h. To add in one year nearly 40 miles to the Macchi record is no mean achievement, indeed.

The second significant thing is the speed of the last race itself. To an ordinary mind 280 m.p.h. is meaningless. It acquires, however, a significance when we think that such a speed is equivalent to 400 ft. per sec. and that the velocity of sound is only 1100 ft. per sec. Also 280 miles means roughly a flight from New York to Washington in 50 min. The question may occur, What is the value of such a speed? Is it merely a mechanical stunt or is there a true necessity for flying at such rates? One use for speeds of that order is already indicated very clearly. In warfare there is a constant race between methods of attack and methods of defense. Just as the increase in size of guns on battleships led to heavier armor and heavier armor called for still larger guns, so the appearance of the airplane led to the development of powerful high-angle-fire machine guns and extremely efficient methods of rapid sighting. In daytime under present conditions an ordinary airplane is a very poor risk when flying over a properly equipped battlefield at altitudes below 10,000 ft. From such a height it is difficult to discover the true disposition of the enemy's forces, particularly if the enemy is at all skilful in the employment of camouflage, and yet it is highly important at all times to know the disposition of the enemy's forces especially in these days of great mobility when the positions of tank corps and motorized artillery equipment may be radically changed in a couple of hours.

It is here that the 250-m.p.h. airplane comes into its own. At such a speed a plane is practically absolutely safe from aimed shots and can be hit only by stray bullets or that kind of steady barrage which obviously cannot be maintained for more than short periods of time. Still, Kipling's engineer, McAndrews, asked whether man would be able to keep pace with the machine. This

question acquires a still more acute significance in this case. A 250-mile machine, perhaps a 350-mile one before the next big show, is now available. Whether a 250-m.p.h. observer is likewise possible remains yet to be seen. However, with the development of air photographic cameras and super-high-speed photography, even the observer may be replaced by mechanical means.

The St. Louis Tornado

ON SEPTEMBER 29 a disruptive whirling wind cut a lane through the residential district of St. Louis, leaving in its wake a hundred dead, thousands injured, and millions of damage. The terror and confusion that came with this noontime death-dealing visitation cannot be described. In a few minutes, not over five, the tornado had covered its path and was gone. St. Louis was harmed but not devastated, and its physical scars will soon be healed.

This was not an unusual storm. A hundred or so like it take an average toll of three hundred lives yearly in the United States during the tornado season from May to October. Unfortunately, it occurred in a densely populated section, and this multiplied the damage and loss of life. Even so, had it come during the darkness or had it entered the business section at noon its list of dead would have been much longer.

Designing structures to withstand tornado stresses must be a weird business. The tornado is the most vicious type of storm, exceeding in violence even the tropical hurricane, one of which visited Florida last year. At St. Louis a wind velocity of 72 miles per hour was officially recorded by the Weather Bureau over a period of five minutes; but from the damage which tornadoes cause it is evident that in some of them velocities of at least 400 miles per hour are reached. One interesting manifestation of the energy loosed at St. Louis was the two steel trolley poles bent flat with the ground and pointing in the direction from which the storm came.

A study of the effects of the tornado, and especially of its action on buildings, will furnish fruitful results in a better understanding of the measures that must be taken to reduce hazard without unnecessarily increasing building cost. In dealing with this as with all other forces of nature, the engineer will profit by harsh experience.

The Divisions Advance

IN TIME of peace our country is faced by many problems demanding massed action if they are to be solved in the most satisfactory manner. Many of these problems are basic, and to give them anything but the best attention would be nothing short of neglect of duty. The great army of engineers within The American Society of Mechanical Engineers may be compared to the army of war time, and to carry the comparison further, the success of any major activity of the Society depends upon the strength of its Professional Divisions—they either aid or retard its advance in direct proportion to the manner in which they grow or deteriorate in their individual activities.

One of the most important functions of the Divisions is the preparation and presentation of papers by leaders in the fields covered, giving the results of experiment or research, and the development of methods or advances in the state of the art. Prior to 1926 this was accomplished through sessions at regular meetings of the Society, or through meetings of Local Sections. This method resulted in a great amount of good for mechanical engineering, but more latitude for the Division to work out their programs was necessary. Participation at the regular meetings only did not promote sufficient freedom of discussion; a direct result of the inability of more than a few men from a given locality to attend, with a consequent dampening effect on enthusiasm born of friendship. National meetings of the Divisions, with the privilege of "running their own shows," were therefore approved by the Council.

The result has been most pleasing. The Wood Industries Division, with its meeting in Chicago during November of last year, was the first to operate under the new ruling. The attendance was encouraging. The meeting of the Aeronautic Division in April of this year in Buffalo showed the effect of the successful start made by the Wood Industries group. Any doubts that may have remained as to the ultimate success of the new arrangement were dispelled by the Fuels Division's Meeting in St. Louis, October 10 to 13, 1927, with an attendance of 700. In this case a forum for all engineers interested in fuels was set up by the Division, and the efforts of the officials were unselfishly devoted to the advancement of the cause of fuels, regardless of the society affiliations of those present.

The Divisions have advanced—that cannot be questioned—with their splendid record already before the profession, there seems no doubt that they will continue to march forward.

Commercial Standardization in the Department of Commerce

THE commercial standardization activities of the United States Department of Commerce are now placed under the guidance of an assistant director of the Bureau of Standards. Dr. George K. Burgess, Director, has announced the appointment of Ray M. Hudson as Assistant Director in charge of commercial standards. According to the same announcement Dr. L. J. Briggs will be Assistant Director in charge of research and testing, with responsibility for the development, construction, custody, and maintenance of reference and working standards; their intercomparison, improvement and application in science, engineering, industry, and commerce. In Dr. Burgess' absence, Dr. Briggs will act as executive head of the Bureau in the supervision of administration of scientific and technical work. He will also continue to function as liaison officer between the Bureau and other governmental branches concerned in aeronautics. Mr. Hudson will supervise the formulation and coördination of commercial standards, with particular reference to the needs of industry. He will be in charge of the Division of Simplified Practice, the Division of Commercial Standards, the section of the work of the division of building and housing relating to codes and standards, the correlation of the work of the Federal Specification Boards with commercial practice and liaison on all questions of commercial standards. Mr. Hudson's place as Chief of the Division of Simplified Practice will be taken by E. W. Ely, formerly assistant chief.

Sixth Exposition of Power and Mechanical Engineering

THE phenomenal growth of the annual Exposition of Power and Mechanical Engineering is an accurate measure of the tremendous advances in the development of mechanical power generating and using machinery. The sixth in the series is to be held at the Grand Central Palace in New York during the week commencing December 5, 1927, paralleling the great annual meetings of The American Society of Mechanical Engineers and the American Society of Refrigerating Engineers. Four floors of the Palace will be completely filled with interesting showings of the latest mechanical devices. Over 500 exhibitors are participating, and their exhibits will cover a wide range. Heat and power generation will occupy a large section with displays of boilers, stokers, furnaces, superheaters, valves, and all the other accessory devices that are essential to the economical generation of steam. There will also be equally interesting showings of heating and ventilating equipment, refrigeration machinery, power-transmission devices, machine tools, woodworking machines, and a comprehensive section of instruments for measuring and recording time, pressure, volume, gas and air flow, temperature, and in fact all of the variables that the engineers in industry must control. The exposition will be a complete mechanical show.

In scope, size, value of exhibits, attendance, and influence on industry the coming event will be an important factor in the future development of industry. Over 100,000 visited the 1926 show and the 1927 event is sure to attract a much larger crowd. Compare it with the first show in 1922 when about 150 exhibitors occupied only one floor and a half and the attendance was only about 20,000. The first show was a success, however, and when the second one filled two floors and more and attracted a larger attendance, the "Power Show," as it was then known, became an established fact as an annual clearing house for the newest and best in power machinery.

TYPICAL SCENE AT THE CLEVELAND MACHINE-TOOL EXHIBITION

National Machine Tool Builders' Exposition at Cleveland

BY JOSEPH W. ROE,[1] NEW YORK, N. Y.

FOR a year or more the builders and users of machine tools have been looking forward to the first exposition of the National Machine Tool Builders' Association, which was held in Cleveland, September 19 to 23, 1927. This has been given careful planning, effective promotion, and much hard work. The splendid outcome has justified the effort, and the promises of the promoters were more than fulfilled. It was the largest machine-tool exhibition ever held in the United States, and its direct benefit to the metal-working industries should be great and long felt.

The choice of Cleveland for holding the show was wise and gave initial assurance of the success. It is located in the active metal-working region of the United States, where Ohio alone, according to recent figures, builds over 25 per cent of the machine tools made in this country.

Germany has a great annual tool exhibit held at Leipzig in a permanent hall built by the Verein Deutscher Werkzeug-Maschinen Fabriken. The Machine Tool Builders' Association was fortunate in having available for its first venture into this field the West Annex of the Cleveland Public Auditorium, in the heart of the city, with trackage connections to both rail and water carriers coming to its doors. Its construction permits the handling and operation of heavy machine tools, and permanent electric-power connections were installed to drive this and future exhibitions.

The main exposition hall is 200 feet wide by 600 feet long, and all on one floor. In spite of the size this space was sold months before the opening and an overflow was necessary which was provided by pressing into service the arcade connecting the hall with the main auditorium. This accommodated 30 additional exhibits. The official catalog shows 181 exhibitors, American firms only being admitted. They exhibited at least 500 separate items, which required about 300 railway cars for their transportation. The power required for the show was approximately 4000 hp. These figures give some idea of the size of this "machine shop." As every item represented the latest development of the art, it is fair to say that no such collection of metal-working machines has ever been brought together.

[1] Professor of Industrial Engineering, New York University. Mem. A.S.M.E.

ATTENDANCE LIMITED TO THOSE REALLY INTERESTED

While the attendance was free, it was necessary to show that you had a real interest in machine tools, after which you were duly tagged for the benefit of the exhibitors and allowed to pass freely. Every leader of importance in the machine-tool building and using field appeared to be there. The curious public was conspicuous by its absence. Only a person who has stood behind the firing line at such a show can realize what this meant to the engineers and sales staffs on duty. If you do not grasp this, picture yourself going into great detail to explain a complicated machine for generating some refined cut to a man who proves to be a retail drug clerk.

To go into the details of individual exhibits is beyond the space limitations here. It is possible only to give a few impressions and to indicate some of the high lights.

On entering, the first impression was one of size. The layout, however, was clear, convenient, and supplemented by an adequate guide book. A remarkable order and cleanliness were maintained throughout the entire show. The usual procedure for most visitors was first to make the round of the show to gain a perspective, noting the many items which demanded individual study. In most cases this preliminary survey consumed most of a day, so that many who planned to stay only one day extended their visit.

One of the first impressions from the preliminary survey was that of "clean" design. Motor drives and gears and hydraulic controls have very generally replaced belting and are built into the machines as part of the general design. The unwholesome-looking growths tacked on to designs, so familiar a few years ago, have disappeared.

The second impression was that of increased power behind the cutting tools. None of the machines appeared to be pushed to their limits, but all were carrying amazing cuts with ease. The great contrast between the large and small in machine-shop practice was also

question acquires a still more acute significance in this case. A 250-mile machine, perhaps a 350-mile one before the next big show, is now available. Whether a 250-m.p.h. observer is likewise possible remains yet to be seen. However, with the development of air photographic cameras and super-high-speed photography, even the observer may be replaced by mechanical means.

The St. Louis Tornado

ON SEPTEMBER 29 a disruptive whirling wind cut a lane through the residential district of St. Louis, leaving in its wake a hundred dead, thousands injured, and millions of damage. The terror and confusion that came with this noontime death-dealing visitation cannot be described. In a few minutes, not over five, the tornado had covered its path and was gone. St. Louis was harmed but not devastated, and its physical scars will soon be healed.

This was not an unusual storm. A hundred or so like it take an average toll of three hundred lives yearly in the United States during the tornado season from May to October. Unfortunately, it occurred in a densely populated section, and this multiplied the damage and loss of life. Even so, had it come during the darkness or had it entered the business section at noon its list of dead would have been much longer.

Designing structures to withstand tornado stresses must be a weird business. The tornado is the most vicious type of storm, exceeding in violence even the tropical hurricane, one of which visited Florida last year. At St. Louis a wind velocity of 72 miles per hour was officially recorded by the Weather Bureau over a period of five minutes; but from the damage which tornadoes cause it is evident that in some of them velocities of at least 400 miles per hour are reached. One interesting manifestation of the energy loosed at St. Louis was the two steel trolley poles bent flat with the ground and pointing in the direction from which the storm came.

A study of the effects of the tornado, and especially of its action on buildings, will furnish fruitful results in a better understanding of the measures that must be taken to reduce hazard without unnecessarily increasing building cost. In dealing with this as with all other forces of nature, the engineer will profit by harsh experience.

The Divisions Advance

IN TIME of peace our country is faced by many problems demanding massed action if they are to be solved in the most satisfactory manner. Many of these problems are basic, and to give them anything but the best attention would be nothing short of neglect of duty. The great army of engineers within The American Society of Mechanical Engineers may be compared to the army of war time, and to carry the comparison further, the success of any major activity of the Society depends upon the strength of its Professional Divisions—they either aid or retard its advance in direct proportion to the manner in which they grow or deteriorate in their individual activities.

One of the most important functions of the Divisions is the preparation and presentation of papers by leaders in the fields covered, giving the results of experiment or research, and the development of methods or advances in the state of the art. Prior to 1926 this was accomplished through sessions at regular meetings of the Society, or through meetings of Local Sections. This method resulted in a great amount of good for mechanical engineering, but more latitude for the Division to work out their programs was necessary. Participation at the regular meetings only did not promote sufficient freedom of discussion; a direct result of the inability of more than a few men from a given locality to attend, with a consequent dampening effect on enthusiasm born of friendship. National meetings of the Divisions, with the privilege of "running their own shows," were therefore approved by the Council.

The result has been most pleasing. The Wood Industries Division, with its meeting in Chicago during November of last year, was the first to operate under the new ruling. The attendance was encouraging. The meeting of the Aeronautic Division in April of this year in Buffalo showed the effect of the successful start made by the Wood Industries group. Any doubts that may have remained as to the ultimate success of the new arrangement were dispelled by the Fuels Division's Meeting in St. Louis, October 10 to 13, 1927, with an attendance of 700. In this case a forum for all engineers interested in fuels was set up by the Division, and the efforts of the officials were unselfishly devoted to the advancement of the cause of fuels, regardless of the society affiliations of those present.

The Divisions have advanced—that cannot be questioned—with their splendid record already before the profession, there seems no doubt that they will continue to march forward.

Commercial Standardization in the Department of Commerce

THE commercial standardization activities of the United States Department of Commerce are now placed under the guidance of an assistant director of the Bureau of Standards. Dr. George K. Burgess, Director, has announced the appointment of Ray M. Hudson as Assistant Director in charge of commercial standards. According to the same announcement Dr. L. J. Briggs will be Assistant Director in charge of research and testing, with responsibility for the development, construction, custody, and maintenance of reference and working standards; their intercomparison, improvement and application in science, engineering, industry, and commerce. In Dr. Burgess' absence, Dr. Briggs will act as executive head of the Bureau in the supervision of administration of scientific and technical work. He will also continue to function as liaison officer between the Bureau and other governmental branches concerned in aeronautics. Mr. Hudson will supervise the formulation and coördination of commercial standards, with particular reference to the needs of industry. He will be in charge of the Division of Simplified Practice, the Division of Commercial Standards, the section of the work of the division of building and housing relating to codes and standards, the correlation of the work of the Federal Specification Boards with commercial practice and liaison on all questions of commercial standards. Mr. Hudson's place as Chief of the Division of Simplified Practice will be taken by E. W. Ely, formerly assistant chief.

Sixth Exposition of Power and Mechanical Engineering

THE phenomenal growth of the annual Exposition of Power and Mechanical Engineering is an accurate measure of the tremendous advances in the development of mechanical power generating and using machinery. The sixth in the series is to be held at the Grand Central Palace in New York during the week commencing December 5, 1927, paralleling the great annual meetings of The American Society of Mechanical Engineers and the American Society of Refrigerating Engineers. Four floors of the Palace will be completely filled with interesting showings of the latest mechanical devices. Over 500 exhibitors are participating, and their exhibits will cover a wide range. Heat and power generation will occupy a large section with displays of boilers, stokers, furnaces, superheaters, valves, and all the other accessory devices that are essential to the economical generation of steam. There will also be equally interesting showings of heating and ventilating equipment, refrigeration machinery, power-transmission devices, machine tools, woodworking machines, and a comprehensive section of instruments for measuring and recording time, pressure, volume, gas and air flow, temperature, and in fact all of the variables that the engineers in industry must control. The exposition will be a complete mechanical show.

In scope, size, value of exhibits, attendance, and influence on industry the coming event will be an important factor in the future development of industry. Over 100,000 visited the 1926 show and the 1927 event is sure to attract a much larger crowd. Compare it with the first show in 1922 when about 150 exhibitors occupied only one floor and a half and the attendance was only about 20,000. The first show was a success, however, and when the second one filled two floors and more and attracted a larger attendance, the "Power Show," as it was then known, became an established fact as an annual clearing house for the newest and best in power machinery.

TYPICAL SCENE AT THE CLEVELAND MACHINE-TOOL EXHIBITION

National Machine Tool Builders' Exposition at Cleveland

BY JOSEPH W. ROE,[1] NEW YORK, N. Y.

FOR a year or more the builders and users of machine tools have been looking forward to the first exposition of the National Machine Tool Builders' Association, which was held in Cleveland, September 19 to 23, 1927. This has been given careful planning, effective promotion, and much hard work. The splendid outcome has justified the effort, and the promises of the promoters were more than fulfilled. It was the largest machine-tool exhibition ever held in the United States, and its direct benefit to the metal-working industries should be great and long felt.

The choice of Cleveland for holding the show was wise and gave initial assurance of the success. It is located in the active metal-working region of the United States, where Ohio alone, according to recent figures, builds over 25 per cent of the machine tools made in this country.

Germany has a great annual tool exhibit held at Leipzig in a permanent hall built by the Verein Deutscher Werkzeug-Maschinen Fabriken. The Machine Tool Builders' Association was fortunate in having available for its first venture into this field the West Annex of the Cleveland Public Auditorium, in the heart of the city, with trackage connections to both rail and water carriers coming to its doors. Its construction permits the handling and operation of heavy machine tools, and permanent electric-power connections were installed to drive this and future exhibitions.

The main exposition hall is 200 feet wide by 600 feet long, and all on one floor. In spite of the size this space was sold months before the opening and an overflow was necessary which was provided by pressing into service the arcade connecting the hall with the main auditorium. This accommodated 30 additional exhibits. The official catalog shows 181 exhibitors, American firms only being admitted. They exhibited at least 500 separate items, which required about 300 railway cars for their transportation. The power required for the show was approximately 4000 hp. These figures give some idea of the size of this "machine shop." As every item represented the latest development of the art, it is fair to say that no such collection of metal-working machines has ever been brought together.

[1] Professor of Industrial Engineering, New York University. Mem. A.S.M.E.

ATTENDANCE LIMITED TO THOSE REALLY INTERESTED

While the attendance was free, it was necessary to show that you had a real interest in machine tools, after which you were duly tagged for the benefit of the exhibitors and allowed to pass freely. Every leader of importance in the machine-tool building and using field appeared to be there. The curious public was conspicuous by its absence. Only a person who has stood behind the firing line at such a show can realize what this meant to the engineers and sales staffs on duty. If you do not grasp this, picture yourself going into great detail to explain a complicated machine for generating some refined cut to a man who proves to be a retail drug clerk.

To go into the details of individual exhibits is beyond the space limitations here. It is possible only to give a few impressions and to indicate some of the high lights.

On entering, the first impression was one of size. The layout, however, was clear, convenient, and supplemented by an adequate guide book. A remarkable order and cleanliness were maintained throughout the entire show. The usual procedure for most visitors was first to make the round of the show to gain a perspective, noting the many items which demanded individual study. In most cases this preliminary survey consumed most of a day, so that many who planned to stay only one day extended their visit.

One of the first impressions from the preliminary survey was that of "clean" design. Motor drives and gears and hydraulic controls have very generally replaced belting and are built into the machines as part of the general design. The unwholesome-looking growths tacked on to designs, so familiar a few years ago, have disappeared.

The second impression was that of increased power behind the cutting tools. None of the machines appeared to be pushed to their limits, but all were carrying amazing cuts with ease. The great contrast between the large and small in machine-shop practice was also

evident. On the one hand laboratory methods, as for instance, the use of the light-wave method of measurement based upon a unit of 1/50,000 of an inch, were there in a practical form. At the same time there were planers, planer-type milling machines, boring machines, automatic chucking machines, etc. of heroic size, and through all there was evident a tightening down of dimensional working limits. Time today is the most valuable raw material in the machine shop. The end sought in the design of every machine tool was to save time and to hold accuracy to limits insuring complete interchangeability, this being an important element in time saving when the work reaches the assembly stage.

Machines Have at Last Apparently Caught Up with Their Cutting Tools

Since the introduction of high-speed steel a quarter of a century ago, machine-tool builders have tried to push their cutting tools to the limit made possible by tool steels, but they have usually only approached this. At the same time the limit was constantly being raised by metallurgical improvements. The Cleveland exposition indicates that at last the machines have caught up with their cutting tools. The factors contributing to this are the adoption of more massive designs, correct from the engineering standpoint, which allow the application of much greater power, and the use of anti-friction bearings on spindles and other vital points, coupled with the use of super-accurate gears, including hardened and ground spur and helical types, which carry high speeds and heavy pressures without heating, noise, or vibration. This condition was well brought out during the exposition by the remark of one operator as he removed a cutting tool, that had failed, from a machine tool, which latter showed no signs of distress. He said, "If they expect me to push this machine to the limit, those steel fellows will have to come through with something new."

Review of Operation Refinements and Outstanding Trends in Design as Revealed at Cleveland

Not only have the speed and feed limits been raised, but designs are reducing the idle time as far as possible. Machines with multiple tool positions are increasingly common. They index almost instantly, using uniformly accelerated and retarded motion to reduce the shock. Work tables and tool slides are snapped back to starting position at many times their working speed, collapsible taps and dies allow direct withdrawal, and the chucking and releasing of individual pieces are accomplished by pneumatic or hydraulic means. A speaker at one of the technical sessions used the term "intergrated production" to describe the action of the growing number of multi-spindle and multi-tool machines which carry on many operations at once.

With time recognized as such a valuable element in production, it was evident that close attention has been paid of late to handiness of machine tools. In the earlier designs of many production tools the mechanical considerations eclipsed consideration of the operators, with the result that the time of the operators was wasted, they were unduly fatigued by their work, the net result of this overlooking of the human element being that the possible mechanical efficiency of the machines was rarely achieved.

The refinement of machine tools for comfortable and efficient operation has been brought about in part by pressure exerted by the users upon the builders, in part by the fact that after overcoming difficult mechanical problems the designers have had time to review and refine their work, and in part by the efforts of manufacturers of such accessories as electrical controls, electrical, mechanical, pneumatic, and hydraulic chucking devices, pneumatic and electric hoists, etc. to adapt their devices to machine tools. At the Cleveland Show most of the machines had their controls centralized at the logical operating point, and the station-type machines were so arranged that the work came to the operator rather than demanding that the operator chase after the work. This last indicated a better understanding of material-handling methods on the part of machine-tool builders and the application of these methods within the machines themselves.

With motor drives, geared heads, anti-friction bearings, and cam-operated automatic controls generally accepted, hydraulic feed and control was the outstanding new development and attracted much attention. Not only were powerful hydraulic broaching machines and hydraulic grinders with smooth and precise action in evidence, but there were also drilling machines and heavy milling machines which conclusively demonstrated the possibilities of hydraulic feed and control in the broad field of production machine tools. These machines aroused as much interest among the machine-tool builders as among the tool users and impetus was unquestionably given to the common application of this type of feed and control to such machines as engine lathes, turret lathes, and automatic machines for bar and chucking work.

Stimulating Effects of Exposition on Sales and on Better Engineering and Marketing Methods

The immediate effect of the Cleveland Machine Tool Exposition has undoubtedly been the stimulation of sales. How much of this is new business and how much deferred business remains to be seen, as many tool users have been awaiting this show before ordering new equipment. Many others, however, have been converted by this Exposition to the necessity of installing up-to-date equipment and will be purchasers of new tools.

A secondary effect has been the stimulation within the machine-tool industry itself in better engineering and marketing methods. Examples of this are the recent adoption of certain important standards, the serious consideration of others, and the adoption of simplified practice; also the consideration of what "service to customers" should comprise. With the race in the design of production machine tools obviously a very close one, ingenuity in tooling and "service to customers" are becoming more and more important factors in getting and holding business.

The Exposition should quicken in the minds of tool builders a pride in their profession. Theirs is a large, important industry with a long and honorable history behind it and tremendous responsibilities ahead. The exposition justified their claim that they are the builders of the "master tools of industry."

During the exposition there was inaugurated the first Machine Tool Congress, which is intended to be a "forum of the industry." A constitution was adopted and officers elected. Technical sessions were held on four days with papers and discussions covering engineering and business phases of the industry and also standardization. This is an evidence of the tendency in trade associations to include technical considerations in their field. The A.S.M.E. recognizes this and will be glad to coöperate with them in every possible way, especially through its Professional Divisions, thereby strengthening the usefulness of both types of organizations.

While Success of Cleveland Exhibition Was Widely Recognized, Future Plans Remain Indefinite

It was freely recognized on all sides at the Exposition that it was a success. Most of those present felt that it should be repeated, but these seemed to have differing opinions as to how often. Some said every year, others, every two, three, and even four years. It is a heavy expense to exhibitors and the question was raised whether enough *new* designs were being developed to justify an exposition annually.

The great merit in this one was in the wealth of new designs brought out. In this respect it was clearly ahead of the exhibit at Leipzig this spring. That was larger, and better housed in the permanent building built for the purpose, but it was distinctly inferior to the Cleveland exhibit in the originality of designs and the progress shown. The Leipzig exposition is held annually, and possibly this may be one reason why there were not so many new developments there as at Cleveland.

The question of their future policy came up for official action at the annual meeting of the National Machine Tool Builders' Association at Lenox, Mass., on October 11, and by a rather close vote it was decided not to hold their exhibition next year. There is a feeling on the part of American machine-tool builders, it may be explained at this point, that a national exhibition held annually will be conducive to the stimulation of yearly models—a condition which the economics of the machine-tool industry will not profitably permit. There was, however, at Lenox a prevailing sentiment that in due time the Association should hold another National Machine Tool Show. Whatever their decision may eventually be as to this, they are certainly to be congratulated upon their first show. It was a valuable contribution to American engineering.

Regional Meeting of the A.S.M.E. in Seattle

THE Regional Meeting of the A.S.M.E. in Seattle, Wash., August 29, 30, and 31, was a distinct success. It was bound to be. Its setting in one of the most scenically beautiful sections of the picturesque Northwest was in itself a guarantee. The program, combining a plentiful measure of entertainment along with the valuable and important papers and discussions, was prepared for and conducted with all the vim and enthusiasm for which the West is famous.

The Olympic Hotel had been selected as headquarters and for holding all technical sessions, and here the first one was called to order on Monday, and was devoted largely to the pulp and paper industry. Following a luncheon with the Council an inspection trip was made in the afternoon to the Boeing Airplane Company's establishment and the Washington Iron Works, as well as a beautiful trip along the Lake Shore and Boulevard Drive. In the evening the guests were entertained at a theater party. Tuesday morning's session was largely devoted to harbor machinery and the manufacture and handling of beet sugar. It was followed by a special luncheon with the business men of Seattle. In the afternoon a tour of inspection took the guests to the port of Seattle, the ocean terminals, an electrified sawmill, the Government locks, and the Scenic Drive. In the evening there was an informal banquet and dance. Wednesday was devoted to an exceptionally delightful excursion. This carried the visitors across Puget Sound by boat to the U. S. Navy Yard at Bremerton, and thence along the shores of Hood's Canal, the return trip being made at sundown.

The Technical Sessions

The opening meeting on Monday was called to order by the chairman, H. G. Bastian, of the Oregon Section at 10:00 a.m. The first paper, The Pulp and Paper Industry and the Pacific Northwest, was presented by its author, C. C. Hockley. The paper discussed the economics of the industry, and in presenting it the author stated that his figures came either from the United States Department of Commerce and from trade associations or were figures which he had personally collected in over twenty years of business as a manufacturer, and that he felt they could be safely relied on.

The second paper, Investigation of the Pulp and Paper Industry, by C. Konzo and B. W. Ross, members of the Student Branch of the University of Washington, was presented before any discussion on Mr. Hockley's paper, because, as Chairman Bastian explained, the papers were considered so much of the same nature that it seemed wiser to present them together and then call for a general discussion. In the absence of the authors the paper (one of the prize papers presented last spring at the Student's Session of the Society) was read by Mr. Edmonds of the University of Washington.

In the absence of the author, Prof. R. L. Daugherty then read a paper by F. W. Lake, Superintendent of Production of the Union Oil Company, Los Angeles, on Gas Lift as Applied in Oil Production. In the discussion that followed, Professor Daugherty, replying to a question by Mr. Arkills, said that there was no practical danger of explosion of the gas, because air was seldom mixed with the gas, and in the cases where air had been used the gas did not get to a temperature high enough to cause an explosion. In response to a question by Thomas W. Davis, he explained that under the circumstances outlined in the paper, where the gas was used merely to get oil out of the well, the well to which the gas was applied increased its rate of flow, while a well pumped by mere mechanical pumping did not. He further stated that the mechanical efficiency of the pumping was probably around 40 per cent, ranging from 10 to 60 per cent. He advised S. H. Graf that probably the yield of casinghead gasoline was increased and that the method made emulsion more difficult and expensive to take care of.

W. L. Dudley then brought a verbal message from V. D. Simon, chief engineer of the Washington Pulp and Paper Company, warning against the danger of the public becoming too sanguine of the pulp and paper industry growing rapidly on the Pacific coast. Owing to the very strictly limited market, he felt that the growth of the industry would have to be looked upon as a long-time proposition.

A. C. Estep then read his paper on Modern Diesel Practice, pointing out first that the practice he dealt with was really that of the Pacific Coast rather than of the country in general. In the discussion which followed, Frank Sawford pointed out that designers had been forced to adopt two-cycle engines to get large enough capacity without undue increase in weight. He further pointed out that the true Diesel engine was an air-injection engine and not a solid-injection type such as Mr. Estep favored. While agreeing that a solid-injection engine was not the original Diesel design, both E. Kwartz and the author defended them as more satisfactory. To a question by H. W. Beecher, the author replied that increase in the horsepower of the engines was met by putting in two spray valves instead of one. The session closed with a paper entitled A Smoke Meter, by Frank Sawford, who used slides to illustrate his remarks. Replying to a question asked by A. Le Roy Taylor, the author said that the only limitation on temperature was the melting point of potassium at around 300 deg., and that any method which would prevent this temperature being reached was satisfactory.

Tuesday morning the session was presided over by Charles I. Carpenter. The opening paper, one on Harbor Machinery, was read by the author, Mark R. Colby. It was followed immediately by one on Cargo Cranes, read by its author, Bernard Dunell, and then by the reading of a written discussion of the paper by D. S. Beyer. In the ensuing discussion Willard C. Brinton dealt with the various methods used in Europe and America for handling cargo. He pointed out that the 14-ft. flood level of the River Elbe requires cranes to remove goods in the event of high water, and that the old and low bridges throughout Europe prevented the use of floating cranes such as are used in New York. He discussed the development of the electric trucks in the East and the tractor trailer in the West, and the advantages and disadvantages of each. He further pointed out the advantages of the lift truck in its latest development.

The next paper, on Beet-Sugar Manufacture, written by W. Y. Cannon, was read by Prof. A. L. Taylor in the absence of the author. This was followed by a paper on Sugar-Warehouse Conveying Systems, prepared by J. T. Buzzo and read by Mr. Edmonds. The next paper dealt with Railway Roller Bearings. As W. C. Sanders, the author, was unable to be present, it was read by H. S. Downs, a business associate, who showed a number of slides in illustration.

A paper entitled Performance Data on Centrifugal Fans, prepared by Messrs. G. S. Wilson, H. J. McIntyre, and W. L. Dudley, was then read by Mr. Wilson. He explained that the title had been changed to The Effect of Entrance and Discharge Angles on Performance of Centrifugal Fans. Mr. Edmonds then read three written discussions of the paper presented by Messrs. H. F. Hagen, M. G. Robinson, and F. R. Still, which will be published later in Quarterly form. At the conclusion of the session Mr. Colby presented some moving pictures illustrating the paper on harbor machinery he had read earlier in the session.

In This Issue

A.S.M.E Annual Meeting Program
Pages 1263-1264

Synopses of the Annual Meeting Papers
Pages 1265-1271

Request Blank for Papers
Page 1272

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The Industrial Transition in Japan

THE INDUSTRIAL TRANSITION IN JAPAN, by Maurice Holland. National Research Council and Japan Society, New York, 1927. Boards, $4^3/_8 \times 6^3/_8$, 51 pp., $1.

THIS book deals with the present state of such Japanese industries as pearl culture, fisheries, and silk, as well as with civil aviation and industrial research. A few years ago there were serious troubles in Japanese industry, but these either were or are being ironed out. Of late several important financial institutions in Japan have gotten into serious trouble. Nevertheless, if one may judge by the facts presented in Mr. Holland's book, Japan is making solid progress and is on the way to working out her own salvation. According to this book, Japan is no longer dependent upon an imported technology. Thirty thousand engineers are enrolled in the membership of her national engineering societies. Young Japanese engineers, graduates of Japanese universities, are gradually taking over the administration and technical control of industrial processes and manufactures. In fisheries technology Japan leads the world, and the high degree of scientific progress she has made in this field is attested by the success of pearl-culture operations in her country.

One of the most interesting sections of the book to mechanical engineers deals with industrial research. The whole range of industry is represented in research laboratories for fuel, nitrogen, pottery, iron, and steel, electrotechnics, brewing, aeronautics, silk, and sericulture. Of the ninety research institutions listed by the Department of Commerce and Industry, twenty-three are supported by the National Treasury and include the National Institute of Physical and Chemical Research, Imperial Combustibles Research Laboratory, Tokyo and Osaka Industrial Research Laboratories, Imperial Sericulture Experimental Stations, and others. Forty-four research institutes are supported by prefectures and municipalities, while twenty-three are attached to private concerns in industry.

The National Institute of Physical and Chemical Research is by far the most important, largest, and best-equipped research institute in Japan. It was founded in 1917 with a total fund of about three and a half million dollars. Out of a personnel of three hundred in this organization, one hundred and twelve are actual research workers.

The Tokyo Research Institute Laboratory is a national laboratory supported by the Imperial Government. It operates in close contact with and in the interest of all industries in Japan. In function it is the one which is most similar to the Bureau of Standards in the United States, although the principal effort of its research investigations is in the development of process technology and new products rather than standards.

The Institute is divided into five sections, including one on chemical analyses; a section dealing with oils, wax, cellulose, woods, pigments, and non-metallic substances; a section for cement, tile, and building material; one for coal-tar derivatives, dyestuffs, and their applications in industry; and a fifth specifically charged with researches in iron and steel, mechanical testing, reinforced-concrete structures, and electroplating.

In the oil-testing section a number of experiments are in progress for the perfection of methods and devices for the recovery and refinement of used oil. Although the product is of different color and of comparatively low market value, there is enough margin in recovery costs to allow the product to compete with new oil.

A chemically pure substance known as "Squalene" has been produced from shark liver oil, and shows great possibilities as a base for transformer oil. Since there are no impurities in the substance, it eliminates the possibilities of sludging, which has been the principal difficulty to be overcome in the development of transformer oils.

Difficulties, particularly in the matter of warping of the wood base, are encountered in the production of lacquer ware, which is used extensively at home in Japan and manufactured for export. Investigations are therefore in progress to develop light metal substitutes to replace wood in this ware. The application of lacquer to the polished surface of metal has been successfully accomplished. Up to the present time, however, no light alloy has been developed which has the equivalent weight of wood and at the same time the absorptive characteristics which will permit the surface finish required in lacquer ware. Considerable effort is being made to develop new types of decorative lacquer, particularly gold lacquer, gold lacquer with semi-precious-metal or gem dust, and other substances which will enhance the artistic appearance of the product.

Formerly the patentable discoveries resulting from research investigations were published freely, and all industries were at liberty to use them at will. Under present practice, when a patentable device is perfected by the Institute, the Department of Home Industry of the Government makes an investigation of the industry in which the patent is to be placed and recommends to the officials of the Institute two or three reliable concerns to which the exclusive right to manufacture is subsequently given. This procedure was found to be necessary by previous experience, since upon the development of a new product or device a number of competitors would rush into manufacturing and only one or two would survive, with the result that the number of failures was a matter of concern to the Government. Hence the present system has been developed. In this Government-supported institute there is no provision for the inventor to share in the royalties accruing from the industrial application of the device. The royalties resulting from the sale of completed products are made directly to the Finance Department of the Government, and not credited to the Tokyo Industrial Research Institute.

In general, the trend of research in Japan is toward an economical utilization of natural resources and a refinement of industrial processes, the substitution of cheaper materials, and the mass production of articles which can be sold cheaply at home and abroad, rather than an organized effort to produce original processes or technique through scientific research.

Considering the relative amounts of funds (including Government subsidies) expended on research, the number of research institutes, their housing, equipment, personnel, and organization, the author places Japan in the fourth position in the organization of industrial research among the industrial nations of the world.

Books Received in the Library

AIRPLANE DESIGN; Aerodynamics. By Edward P. Warner. McGraw-Hill Book Co., New York, N. Y., 1927. Cloth, 6 × 9 in., 598 pp., diagrams, $7.50.

Professor Warner has endeavored to provide a textbook for the student interested in the practical application of aerodynamic

theories to design. He has tried to systematize, correlate and coördinate the results of the great mass of experimental data which has been accumulated, and to present the results in a way which can be understood by a student of moderate mathematical attainments. The book is based upon extensive experience as a designer and teacher.

AIRSHIP DESIGN. By Charles P. Burgess. Ronald Press Co., New York, 1927. (Ronald Aeronautic Library.) Cloth, 6 × 9 in., 300 pp., illus., diagrs., tables, $9.

A useful contribution to the meager literature on airship design, in which attention is paid particularly to the rigid type. The author assumes a knowledge of the theory of beams, columns, and frame structures, and confines himself to the theorems and methods of calculation that are peculiar to airship design.

The first chapter discusses the choice of type; the second, the calculation of size and performance. Succeeding chapters deal with volumes and dimensions, moments, aerodynamic forces, strength of airships, gas-pressure forces, design of girders, steps in design, and common fallacies. The work is intended as a textbook for students and a handbook for designers.

AMERICAN AIRCRAFT DIRECTORY. 1927. Aviation Publishing Corporation, New York, 1927. 9 × 12 in., 176 pp., illus., Paper, $3; cloth, $5.

Covers commercial and governmental air activities in the United States. The work of the Department of Commerce, the Post Office, the Army, the Navy, and the Coast Guard is described in detail and the personnel in charge of aviation listed. Lists of national and local aeronautical associations, of colleges that teach aeronautics and of graduate aeronautical engineers are given. The laws and rules governing flying are given in full. A geographical directory of landing fields, aviators, and supply companies, and a directory of builders and manufacturers of equipment complete the book.

ANLASSVORGÄNGE IN ABGESCHRECKTEN KOHLENSTOFFSTAHLEN. By L. Traeger. (Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 294.) V.D.I. Verlag, Berlin, 1927. Paper, 9 × 12 in., 20 pp., illus., diagrs., 3.80 r.m.

In this pamphlet the changes in length of hardened carbon steels during annealing are investigated and compared with the changes in other of their properties. The various methods of research are described, their results discussed critically and an explanation of the process of annealing given. This is not, according to the author, in a gradual decomposition of the martensite, but consists of three transformations at definite temperatures, each accompanied by changes in length, structure, electrical resistance, solubility, and strength. These transformations are explained and methods for determining the proper temperature and time in annealing practice are given.

THE ANTHRACITE RAILROADS. By Jules I. Bogen. Ronald Press Co., New York, 1927. Cloth, 6 × 9 in., 281 pp., map, $4.25.

A detailed study of each of the seven great coal roads from its inception to the present day. Describes their evolution, their dominance of the anthracite industry, the segregation of their coal properties, and their future development. The effects upon each company of the economic and financial developments of the time are pointed out.

BERECHNEN UND ENTWERFEN VON TURBINEN-UND WASSERKRAFT ANLAGEN. By P. Holl, revised by E. Glunk. Fourth edition. R. Oldenbourg, Munich and Berlin, 1927. Cloth, 6 × 9 in., 187 pp., illus., 10.50 r.m.

This book, the work of an experienced engineer, describes concisely the various steps in designing a hydraulic power plant. The necessary calculations are outlined, the essential constants and other data are given, and their use is illustrated by several examples. The primary object of the work is to call attention to the Holl Turbine Slide Rule, but the methods outlined may be used without that instrument.

COAL CARBONIZATION. By John Roberts. Isaac Pitman & Sons, London and New York, 1927. Cloth, 6 × 9 in., illus., diagrs., 406 pp., $7.50.

An account of the principles and processes of coal treatment which have been proposed or used for making coke and semi-coke and for the recovery of by-products from coal.

After discussing the origin of coal, its coking properties, and the factors that affect coking, low-temperature carbonization processes are treated in detail. Attention is then turned to high-temperature carbonization and by-product recovery, after which gasworks practice is treated. A chapter is devoted to methods for producing oil from coal.

ELECTRIC ELEVATORS. By F. A. Annett. McGraw-Hill Book Co., New York, N. Y., 1927. Cloth, 6 × 9 in., 447 pp., illus., diagrams, $5.

This is a welcome addition to the scanty literature on modern elevators. It is descriptive rather than theoretical, and while all types of electric elevators are included, the emphasis is placed upon the latest designs. The book will be useful to those who select and operate elevators.

FOREMANSHIP AND SUPERVISION. By Frank Cushman. John Wiley & Sons, New York, 1927. Cloth, 5 × 8 in., 238 pp., illus., $2.50.

The author discusses the value of the conference as a means of education, the methods of holding conferences, the duties and qualifications of those leading them, and the results that may be expected. The use of conferences to train foreman and to train teachers and supervisors of vocational education is illustrated in detail.

GENERAL PHYSICS. By Henry Crew. Fourth edition. Macmillan Co., New York, 1927. Cloth, 6 × 9 in., 674 pp., illus., diagrs., $4.

The author's purpose is the presentation, in an elementary manner, of the facts that are most essential for presentation to first-year and second-year college students, with the philosophy which most simply connects them. The book is a clearly written textbook, in which the attention of the student is held by the way in which the principles are illustrated by phenomena with which he is familiar. The revision has incorporated the results of recent discoveries in physics.

HEATING AND VENTILATING. By Charles L. Hubbard, revised by Wm. H. Severns. American Technical Society, Chicago, Ill., 1927. Cloth, 6 × 9 in., 230 pp., illus., tables, $3.

An elementary practical textbook on the design and construction of heating and ventilating plants.

DIE KONDENSATWIRTSCHAFT. By Hans Balcke. R. Oldenbourg, Munich and Berlin, 1927. Paper, 6 × 9 in., 219 pp., illus., diagrs., 10 r.m.

The condenser, as viewed by Dr. Balcke, is no longer merely an apparatus for precipitating waste steam under certain conditions, but today is also a valuable apparatus for preparing feedwater and a preheating plant for all purposes. Condenser engineering begins at the exhaust of the engine and ends only with the injection of prepared, heated feedwater into the boiler.

This book discusses condenser practice in stationary steam plants as a self-contained department of heat engineering. It assists the power-plant engineer to evaluate his plant from the viewpoint of heat economy and to utilize waste heat to the fullest degree. It takes up the various units of the power plant, points out the losses of heat and energy in each and shows how to avoid or utilize them. It teaches that condensation practice is in fact a special branch of chemical technology, and pleads for consideration of its problems from a modern point of view.

LEHRGANG DER HÄRTETECHNIK. By Joh. Schiefer and E. Grün. Third edition. Julius Springer, Berlin, 1927. Paper, 6 × 9 in., 211 pp., illus., diagrams, tables, 7.50 r.m.

A practical textbook on hardening and tempering for tool makers. The book first explains the physical and chemical properties of steel, the methods of manufacture and the common physical tests. The arrangement and equipment of tempering shops are then described, after which the tempering and hardening of tools for various purposes are discussed in detail.

LOCKS AND LOCKMAKING. By Francis J. Butter. Isaac Pitman & Sons, New York and London, 1926. (Common Commodities & Industries.) Cloth, 5 × 7 in., 135 pp., illus., $1.

Mr. Butter gives an interesting account of the evolution of locks from the earliest types to the most modern, with some information upon the industry. His book is intended primarily for the general reader, but it will also interest engineers, and appears to be the only easily available book upon locks.

LUBRICATION AND LUBRICANTS. By Leonard Archbutt and R. Mountford Deeley. Fifth edition. Charles Griffin & Co., London, J. B. Lippincott Co., Philadelphia, 1927. Cloth, 6 × 9 in., 650 pp., illus., tables, 36 s.

This treatise upon lubricants has long been a standard and is too well known to need an introduction. This edition, the first revision since 1912, has been largely rewritten and rearranged, in the light of recent investigations. A general theory of solid friction is now presented, much new matter on the theory of viscous lubrication has been incorporated, and the chapters on lubricants and their examination have been thoroughly revised and enlarged. The chapter on frictional testing of lubricants has been rewritten. The information on lubricators and on the design of bearings has been much expanded. A chapter on the recovery of lubricating oil has been added.

MATHEMATISCHE HILFSMITTEL FÜR TECHNIKER. By A. Deckert and E. Rother. A. Ziemsen Verlag, Wittenberg, 1927. Cloth, 6 × 8 in. 254 pp., 7.50 r.m.

A collection of formulas and other rules of differential and integral calculus used by engineers and scientists, arranged in convenient form for quick reference.

PERSONNEL. By George R. Hulverson. Ronald Press Co., New York, 1927. (Business administration series.) Cloth, 6 × 9 in., 400 pp., forms, $4.50.

Discusses methods of developing and directing the staff of large business organizations through a personnel department. The technique and objectives of this department are treated in detail, but the problem of its general administrative control is emphasized. The author has tried to summarize the principal features and the limitations of various methods in such a way as to assist the executive in selecting the best plans for his own needs.

PRESSURE AIRSHIPS. By Thomas L. Blakemore and W. Watters Pagon, Ronald Press Co., New York, 1927. (Ronald Aeronautic Library.) Cloth, 6 × 9 in., 311 pp., illus., diagrs., tables, $8.

Discusses the design and construction of airships in which the shape of the envelope is maintained by the pressure of the gas in it. Mr. Blakemore is responsible for the section upon non-rigid airships, Mr. Pagon for that upon semi-rigid types.

Each section considers the general characteristics of the airships, describes the various types, explains the design and construction of hulls, suspensions, controls, cars, and other parts. Erection, inflation, and rigging are described, and many technical data are given. The book aims to provide the information wanted by students, engineers, designers and builders. It is based upon the practical experience of the authors.

PRINTING INK. By Frank B. Wiborg. Harper & Bros., New York and London, 1926. Cloth, 6 × 9 in., 299 pp., illus., $4.

A history of the evolution of printing ink in the various Asiatic and European countries, from antiquity to modern times, with a detailed account of modern methods of manufacture. The author has been intimately connected with the industry for many years, and has brought together a great amount of information that is not easily accessible elsewhere.

PURCHASING. By W. N. Mitchell. Ronald Press Co., New York, 1927. (Business administration series.) Cloth, 6 × 9 in., 385 pp., forms, $4.50.

A study of the purchasing function in business organizations. Basic policies are compared, methods of coördinating the work of the purchasing department with other departments are discussed and the relations of purchasing to the business as a whole are clearly brought forward. The treatment is general, based on the kind of commodities bought and the purposes in buying them, irrespective of routine details for a particular business.

PYROMETRY. By William P. Wood and James M. Cork. McGraw-Hill Book Co., 1927. Cloth, 6 × 9 in., 207 pp., illus., diagrams, $3.

Intended as a textbook for college students, rather than for use as a reference work. Describes the various types of instruments for measuring, recording, controlling temperatures, and discusses transition points and thermal analysis. Problems and outlines for laboratory work are included.

SHIPBUILDING AND THE SHIPBUILDING INDUSTRY. By J. Mitchell. Isaac Pitman & Sons, New York, 1926. (Pitman's Common Commodities and Industries.) Cloth, 5 × 7 in., 116 pp., illus., charts, $1.

This little book gives an excellent account of the way in which a ship is designed and built, written so that an inexperienced reader can understand it. Attention is paid to the problems of material and labor, as well as the problems of engineering, involved in making a ship, and the book should interest many who are curious about these matters.

THEORY AND PRACTICE OF ROLLING OF STEEL. By Wilhelm Tafel. Translated by Richard Rimbach. Penton Publ. Co., Cleveland, 1927. Cloth, 6 × 9 in., 300 pp., diagrams, tables, $6.

A welcome addition to the scanty literature of rolling. The work is an introduction to the theory and understanding of rolling and roll-pass design, and the author endeavors to present the reasoning which is necessary for successful design, rather than a collection of solutions of specific problems. The theories and technical conceptions of rolling are discussed. The design of passes and the arrangement of rolls are studied and the design of passes for merchant bars and shapes requiring equal and unequal draft is discussed in detail. A chapter is devoted to power requirements of roll trains and methods of driving.

THEORY OF MACHINES. By Louis Toft and A. T. J. Kersey. Isaac Pitman & Sons, London and New York, 1927. (Engineering degree series.) Cloth, 6 × 9 in., 408 pp., illus., diagrs., $3.75.

This textbook on the theory of machines covers the course required of engineering students in English universities. Stress is laid upon fundamental principles and a large number of examples illustrating their practical application are provided.

TIME AND MOTION STUDY AND FORMULAS FOR WAGE INCENTIVES. By Stewart M. Lowry, Harold B. Maynard, and G. J. Stegemerten. McGraw-Hill Book Co., New York, 1927. Cloth, 6 × 9 in., 377 pp., illus., charts, tables, $4.

Upon the basis of their practical experience in the time-study department of a large manufacturing concern, the authors of this work present a fully developed time-study and formula system, which incorporates the principles that have stood the test of time, with newer developments. Their book is intended for use as a textbook in the training of students and also as a handbook for practical men and factory executives.

The book first takes up, step by step, the method of making a time study, emphasis being laid upon methods of analyzing and classifying skill and effort, and of determining standard times. Methods for constructing formulas from time-study data are then explained. The final chapters explain the organization and supervision of the time-study, formula, and wage-payment work in any plant. The descriptions are very detailed and definite.

UNTERSUCHUNGEN AN RASCHLAUFENDEN SCHWERÖLMOTOREN INSBESONDERE AM EINZYLINDER-GLÜHKOPFMOTOR "BULLDOG" VON H. LANZ, MANHEIM. By Otto Kehrer. R. Oldenbourg, Munich, 1926. Paper, 8 × 11 in., 111 pp., diagrs., plates. Gift of author.

The author investigated carefully the fuel consumption, efficiency, capacity for overload and reliability of a modern Lanz hot-bulb high-speed oil engine, and compared his findings with those for modern engines of equal size but of other types. The investigation was made with unusual thoroughness, and the methods and results are reported in full detail.

UNTERSUCHUNG VON SCHNECKENTRIEBEN. By Rudolf Gruson. R. Oldenbourg, Munich und Berlin, 1927. (Berlin, Technische Hochschule. Versuchsfeld für Maschinenelemente. Heft 7.) Paper, 8 × 11 in., 27 pp., diagrams, tables, 4 r.m.

Describes tests of a worm gear. A formula for temperature was found and the points of greatest efficiency and the admissible load were determined. The properties of the most suitable oil and the narrowest possible breadth of wheel were ascertained.

VERSUCHE MIT FANGVORRICHTUNGEN AN AUFZÜGEN. By Gerold Weber. R. Oldenbourg, Munich und Berlin, 1923. (Berlin. Technische Hochschule. Versuchsfeld für Maschinenelemente, Feft 5.) Paper, 8 × 11 in., 40 pp., illus., diagrams, 3.20 r.m.

Gives in detail the results of a series of tests of safety brakes for elevators. Four types of brakes were tested, the experiments being made at the testing field of the Berlin Technical High School.

A.S.M.E. Annual Meeting Program

New York, December 5 to 8, 1927

Monday, Dec. 5

Morning: 9:30 A.M.
Council Meeting.
Conference of Local Sections Delegates.

Afternoon: 2:30 P.M.
Council Meeting.
Conference of Local Sections Delegates.

Evening: 8:00 P.M.
Open House.

Tuesday Morning, December 6, 9:30 A.M.

Machine Shop Practice (I)

Symposium on Hydraulic Feeds for Machine Tools:
Characteristics of Hydraulic Feed and Drive for Cutting Tools, WALTER FERRIS.
Hydraulics and Modern Machine-Tool Design, WALDO J. GUILD.
The Development of Hydraulic Feeds on Multiple Drilling Machines, R. M. GALLOWAY.
Hydraulic Feeding Mechanism for Milling Machines, S. EINSTEIN and H. ERNST.

Industrial Power

The Ruths Steam Accumulator, R. A. LANGWORTHY.
Stresses and Reactions in Expansion Pipe Bends, A. M. WAHL.

General (I)

The Steel-Wool Industry, CROSBY FIELD.
The Modern Fire Engine, KARL W. STINSON.

Railroad (I)

Vibration of Bridges, S. TIMOSHENKO (by title).
The Motor Truck and L. C. L. Freight, F. J. SCARR.
Back Pressure and Cut-Off Adjustment for the Locomotive, THOS. C. MCBRIDE.

Tuesday Afternoon, December 6, 2:00 P.M.

Machine Shop Practice (II)

Symposium on Plant and Equipment Maintenance:
Maintenance of Machine Equipment, WILLIAM HARTMAN.
Plant Maintenance and Return on Capital Investment, W. H CHAPMAN.
Maintenance of Shop Equipment, J. R. WEAVER.
Maintenance of Shop Equipment, C. S. GOTWALS.
Plant Maintenance, GEO. H. ASHMAN.

Railroad (II)

Heating and Ventilating of Passenger Cars, EDWARD A. RUSSELL.
Can Accident Prevention Be Reduced to a Science? THOS. H. CARROW.

Joint Session with A.S.R.E.

Heat Transfer, General Formulas, EDWIN R. COX (contributed by A.S.M.E.).
How Shall We Measure Heat Flow of Compound Walls? F. G. HECHLER (contributed by A.S.R.E.).
Effect of Pipe Lengths on Orifice Coefficients, A. J. WOOD (contributed by A.S.R.E.).

Hydraulic

Symposium on Centrifugal Pumps:
Centrifugal Pumps, HERBERT T. DAVEY.
New Method of Separating the Hydraulic Losses in a Centrifugal Pump, MICHAEL D. AISENSTEIN.
Method of Analyzing Performance Curves of Centrifugal Pumps, JOS. LICHTENSTEIN.

Lecture 4:30 P.M.

Address by W. E. WICKENDEN on What the National Engineering Societies Can Do for Engineering Education.

Tuesday Evening, December 6, 8:30 P.M.

Presidential Address and Reception; Award of Melville Medal to L. P. ALFORD.

Wednesday Morning, December 7, 9:30 A.M.

Fuels

The K.S.G. Process of Low-Temperature Carbonization, WALTER RUNGE.
Progress Report, R. T. HASLAM.

Machine Shop Practice (III)

The Development of Machine Tools from a User's Viewpoint, F. C. SPENCER.

Materials Handling

Materials Handling as an Aid to Production, FRANK L. EIDMANN.
Costs of Operation and Savings Effected by Electric Industrial Trucks and Tractors, C. B. CROCKETT and H. J. PAYNE.

Photography

(Joint Session with American Optical Society.)
Present Applications of Photography in Mechanical Engineering, C. E. K. MEES.
Photomicrography and Its Application to Mechanical Engineering, F. F. LUCAS.
X-Ray Photography and Its Application to Mechanical Engineering, W. P. DAVEY.

Wednesday Afternoon, December 7

2:00 P.M.
Business Meeting.

3:00 P.M.
Education and Training for the Industries.
Apprentice Training for Draftsmen, C. J. FREUND.
Principles of Apprenticeship Organization, BEN S. MOFFATT.

3:00 P.M.
Student Branch Conference.

3:00 P.M.
Steam Tables Research.
Reports from Bureau of Standards and M.I.T.

3:30 P.M.
Ladies' Tea.

Wednesday Evening, December 7, 6:30 P.M.

Annual Dinner.

Thursday Morning, December 8, 9:30 A.M.

Management (I)—Jointly with A.M.A.

Control of Factory Overhead, H. G. PERKINS.
Production Control in a Wrought Brass Mill, W. R. CLARK and ARTHUR BREWER.

Central-Station Power

Short-Time Tensile and Expansion Tests on Plain Carbon Steels and Enduro Metal at Elevated Temperatures, A. E. WHITE and C. L. CLARK (by title).
Some Factors in Furnace Design for High Capacity, E. G. BAILEY.
Some Operating Data of Large Steam-Generating Units, HENRY KREISINGER and T. E. PURCELL.

Aeronautics

The Effect of High Temperature on the Materials Used in Aircraft, J. B. JOHNSON (by title).
Oleo Gears for Aircraft, E. E. ALDRIN.
The New Propeller-Type High-Speed Windmill for Electric Generation, E. N. FALES.

General (II)

Analysis of Strains and Stresses in a Wristpin of an Automobile Engine by the Mathematical Theory of Elasticity, G. B. COLLIER (by title).
Nozzles with Rounded Approach for Measuring Flow of Air and Gas, S. A. MOSS.
Destruction Test of a 66-Inch Forged Steel Penstock Pipe, JOHN L. COX.

Thursday Afternoon, December 8, 2:00 P.M.

Management (II)—Jointly with A.M.A.

Budgetary Control, Papers by J. P. JORDAN and H. V. COES.

Research

Symposium on Lubrication:
- Viscosity of Lubricants Under Pressure, M. D. HERSEY and H. SHORE.
- The Effect of Running In on Journal-Bearing Performance, S. A. MCKEE.
- An Investigation of the Performance of Waste-Packed Armature Bearings, G. B. KARELITZ.

Boiler Feedwater (Joint Research Committee on Boiler Feedwater Studies and Power Division)

Progress Report of Executive Committee, with Outline of Plan and Scope for Future Work, S. T. POWELL.
Progress Reports of Sub-Committees of Joint Research Committee on Boiler Feedwater Studies.
Design and Operation of Deconcentrators and Continuous Blow-Down Apparatus, R. C. BARDWELL (Sub-Committee No. 1).
Water Softening by Chemicals, with Special Reference to Combined Systems, C. R. KNOWLES (Sub-Committee No. 2).
Studies on Priming and Foaming of Boiler Waters, with Special Reference to Railroad Practice, C. W. FOULK (Sub-Committee No. 3).
Corrosion of Boilers and Appurtenances, and Plan and Scope of Future Work, F. N. SPELLER (Sub-Committee No. 5).
The Effect of Industrial Wastes on Boiler-Feedwater Problems and Condenser Operation, V. B. SIEMS (Sub-Committee No. 7).
Standardization of Water Analyses, with Recommendations for the Determination of Dissolved Oxygen, CO_2, and Hydrogen-Ion Concentration, HAROLD FARMER (Sub-Committee No. 8).
Bibliography of Boiler Feedwater, with a Review of the Work During the Past Year, GEORGE A. STETSON (Sub-Committee No. 9).

Oil and Gas Power

Parallel Operation Between Alternating-Current Generators, J. W. MORTON and C. JUUL (by title).
Efficiencies of Otto and Diesel Engines, F. O. ELLENWOOD, F. C. EVANS and C. T. CHWANG.
Diesel Locomotives, R. HILDEBRAND.

Henry Robinson Towne Lecture, 4:30 P.M.

The Relationship Between Industry and Taxation—An Economist's Views of a Sound Program for American Business in the Field of Taxation, Prof. T. S. ADAMS.

Synopses of 1927 Annual Meeting Papers

THESE papers, abstracts of which are being published on this and the following pages, are being printed in pamphlet form for the A.S.M.E. Annual Meeting. They may be secured by filling out the blank on page 1272 of this issue.

A New Method of Separating the Hydraulic Losses in a Centrifugal Pump

By MICHAEL D. AISENSTEIN

Testing Engineer, Byron D. Jackson Pump Mfg. Co., Berkeley, Calif.

THE so-called hydraulic losses in a centrifugal pump are composed of friction losses and shock loss. The friction losses are those which are due to resistance offered to the water by the walls of the runner and case. The shock loss may be considered as due to the sudden enlargement of passages.

It is important for the designer to know how the losses are distributed and to have a method of separating them, so that by studying the variation of these losses he may decide in which direction improvement should progress.

The purpose of this paper is to present a method by means of which these losses may be determined separately from the head-capacity curve of a given centrifugal pump. An illustrative example of the equations developed by the author is included.

Oleo Gears for Aircraft

By E. E. ALDRIN

Lieutenant, Air Corps, Material Division, Wright Field, Dayton, Ohio

AFTER describing the various oil damping devices for reducing the landing shocks of airplanes, the author presents a theory and test data for the design of the gravity-return type of "oleo" landing gear. This type depends on the flow of oil past an orifice for the shock-absorbing effect. Tests on several forms of orifice using different fluids under a steam hammer gave satisfactory orifice coefficients for design purposes. Then landing gears designed with the new information were dropped under weights with different combinations of orifice, wheel, and tire through heights varying up to 42 in. and their performance studied in slow-motion pictures and cards from pressure indicators attached to the gears.

Some Factors in Furnace Design for High Capacity

By E. G. BAILEY

President, Fuller-Lehigh Co., Fullerton, Pa.

COMBUSTION requires temperature, turbulence, and time. To burn a given quantity of fuel in a given time and to keep each particle in the furnace for the proper length of time requires a large furnace volume. Because of the expense of large furnaces, it is desirable to reduce the time factor to a minimum by burning coal at high rates of combustion. This is the present tendency.

High temperatures, conducive to rapid and efficient combustion, tend to destroy refractories, water-cooled and other wall structures, so that furnace temperature must be limited.

Turbulence, therefore, is the only factor that can be increased profitably. Turbulence is best accomplished by violently mixing the proper proportions of fuel and air as they enter the furnace. The mixing action should also continue throughout the furnace.

Turbulence minimizes the volume of intensely hot, opaque flame and makes the gases more quickly transparent, thus equalizing furnace-wall temperatures by radiation and reducing damage to boiler tubes and cylinder walls caused by hot spots.

The most difficult part of the combustion process is to burn the minute carbon particles in the furnace gases.

Floating particles of ash cause the greatest troubles in a boiler furnace, particularly if their fusion temperature is below the wall-surface temperature. The fusion point of the ash is the most important controlling factor in establishing the rate of combustion, excess air, labor, and cost of furnace maintenance.

Ash should either be kept below its fusion point and removed dry, or else it should be removed entirely in the liquid state. To burn at high rates of combustion, coal having a low ash-fusion point requires some form of furnace cooling throughout all walls. Water-cooling tubes, connected in with the boiler circulation, have been successful in furnace-wall construction. Ample circulation must be provided; bare vertical tubes must not be exposed to excessive flame temperatures; and the rates of heat absorption into the wall tube must not be greater than into the boiler tubes when using scale-forming water.

Can Accident Prevention Be Reduced to a Science?

By THOMAS H. CARROW

Superintendent of Safety, The Pennsylvania Railroad

THE author concludes that accident prevention can be reduced to a science. This conclusion is based on an analysis of the causes of accidents which shows that approximately ten per cent are due to misadventure and therefore unpreventable, and an analysis of the human factor, to which eighty-five per cent of all accidents are attributable. He stresses the need of complete accident records and of educating the supervisory forces in safety.

Production Scheduling in a Brass Mill

By W. R. CLARK AND ARTHUR BREWER

Respectively, General Works Manager and Manager Mill Production Division of the Bridgeport Brass Company

THIS paper describes the scheduling system which has been worked out satisfactorily during the past two or three years in a brass mill. The object of this system is to give better service to customers, to reduce inventories, and stabilize employment. The paper contains flow sheets of the operations involved and is illustrated by charts and tables showing the variations of flow of material and the mechanism of control. The detailed procedures are outlined. The system accomplishes the following results: it enables careful prediction of the rate of production and means for planning it to meet current business, it enables prompt notification to the customers of the expected date of shipment and insures the fulfilment of this promise; in keeping productive facilities elastic, it permits the control of semi-finished and finished parts, the control and reduction of inventories, and an accurate determination of mill hours and number of employees, the whole stabilizing the production rate and ironing out the fluctuation in cost due to variation in the volume of orders.

Some Essential Principles for Budgetary Control

By H. V. COES

Vice-President, General Manager, Belden Manufacturing Co., Chicago, Ill.

THIS paper presents in condensed form most of the essential principles for the application of budgeting to a business and the effective means for control. Some of the means for securing budgetary control are shown in charts and statements of the following: (1) fundamental operating relationships, (2) comparative results of operation for different sales volumes, (3) manufacturing expense budget, (4) indirect labor control, (5) sales and production coördination, (6) sales quota, (7) department quota, (8) comparison of operating ratios.

Analysis of Strains and Stresses in a Wristpin of an Automobile Engine by the Mathematical Theory of Elasticity

By GUY B. COLLIER

Consulting and Designing Engineer, New York, N. Y.

THE paper presents a mathematical analysis of strains and stresses in a wristpin, showing that wristpins can be made considerably lighter than in present-day practice and still have requisite strength, this being obtained by making certain parts of lesser and others of greater thickness than is now done. This is illustrated by numerical data and (in exaggerated form) by drawings showing how, among other things, inertia losses and motor vibrations can also be reduced.

The author regards the wristpin as a beam fixed at each end and having a fixed load uniformly distributed over its length. The fixing of the load to the pin is effected by means of the bushing and its enclosing sleeve, at the upper end of the connecting rod. The stresses and strains imposed on such a structure are then considered. The system of simultaneous partial differential equations for an elastic cylinder subject to a bending-moment loading are integrated on the basis of knowing the form of the axial-stress intensity. Complete expressions are next obtained for the three orthogonal strain displacements and thence for the radial and tangential stresses at any point of the metallic member; these last two combined with the axial stress give the resultant intensity at points in question. The solution involves certain constants of integration which make it more general in character than the conditions involved in the wristpin application, and the analysis can readily be extended. A numerical illustration of the method is given for a wristpin $1^1/_8$ in. in outside diameter and $^3/_{32}$ in. in radial thickness under certain conditions of service and loading for a motor of 6 in. stroke and $3^3/_4$ in. bore working under stated conditions of pressure, etc. The present calculations show that the parts of the wristpin within the connecting-rod sleeve and the piston bosses can be made of lesser thickness than has previously been considered necessary, while the part of pin in the gap between sleeve and boss should be reinforced or made thicker.

General Heat-Transfer Formulas

By EDWIN R. COX

Engineer, California Gasoline Co., Los Angeles, Calif.

FROM the early dimensional reasoning of Boussinesq, and the later work of McAdams and Frost, Rice, and others, the author develops and presents in this paper a set of general equations involving the film concept of heat transfer and of convenient form for use in the practical design of heat-transfer apparatus.

Destruction Test of a 66-In. Forged Steel Penstock Pipe

By JOHN L. COX

The Midvale Co., Nicetown, Philadelphia, Pa.

THE section of pipe tested is representative of a portion of one section of the penstock of the Big Creek Power Plant No. 2, near Los Angeles, Calif. of the Southern California Edison Co., with the object of determining the elastic limit and ultimate strength, as well as the deformation and behavior under high pressure.

Details and specifications of the pipe section are given as well as a description of the test arrangements and measuring apparatus. The test is described and the results are given in tabular and graphic form.

The pipe reached its elastic limit at a pressure of 2150 lb. corresponding to a tangential stress of 25,000 lb. per sq. in. in the steel of the walls, the measured proportional limit of the steel at the ends being 24,500 lb. The pipe failed at a pressure of 5300 lb., which, by the approximation of the extended Birnie formula, would correspond to a fiber stress of 62,000 lb. per sq. in., compared with an actual tensile strength of 67,750 lb. The external expansion was 6 in. in diameter, or 8.3 per cent. The internal expansion was $6^3/_8$ in. in diameter or 9.63 per cent. The mean expansion of the wall was 8.96 per cent. The reduction in wall thickness at the mid-length of the pipe at the fracture was $^3/_{16}$ in. or 6.25 per cent. The paper closes with a discussion of the results of the test.

Costs of Operation and Savings Effected by Electric Industrial Trucks and Tractors

By C. B. CROCKETT AND H. J. PAYNE

The Society for Electrical Development, Inc., New York, N. Y.

THE authors attempt to show how direct and indirect costs of a material-handling system may be classified and estimated, and apply the methods described to the question of operation of electric trucks. The direct costs of operation are here divided into fixed charges and operating charges, both of which are enumerated and, where possible, estimated. Factors affecting the costs are likewise enumerated, and actual figures of first cost and cost of operation taken from several plants are presented, and the savings due to truck operation pointed out.

Centrifugal Pumps

By H. T. DAVEY

Bexleyheath, Kent, England.

IN THIS paper the author first discusses general considerations regarding losses, disk friction, specific speed, etc. He then sets forth at length the principles governing design of the volute, suction and delivery pipes, impeller, bearings and glands, priming apparatus, valves, etc. He closes by briefly considering materials used in the construction of pumps for various purposes.

Materials Handling as an Aid to Production

By FRANK L. EIDMANN

Associate Professor of Machine Design and Practice, Engineering School, Princeton University, Princeton, N. J.

THE author surveys the materials-handling problem of a plant from eight angles: the design of building and arrangement of equipment, the weight of material handled per pound of finished product, the elimination of hand labor, the effect of the materials-handling methods on inventory, the effect of increased output of the worker, the design of the product to facilitate handling, the selection of the handling equipment, and attempts to facilitate handling in shipment and in customer's plant. Examples of good and bad practice are quoted, and illustrations of some are included.

Hydraulic Feeding Mechanism for Milling Machines

By S. EINSTEIN AND H. ERNST

With Cincinnati Machine Co., Cincinnati, Ohio, Mr. Einstein being Chief Designer

AFTER giving a brief history of the development of power-driven feeding mechanisms for milling machines generally, the authors describe a hydraulic system which they believe meets the conflicting requirements which a power-driven feeding device on milling machines should satisfy. The operating characteristics of a hydraulic feeding device are stated and the various circuits such as the feeding, rapid traverse, etc. are described. The purpose of the differential pressure-control valve is stated and the device illustrated and described. By lowering the ideal pressure as compared with that required by the simple relief-valve system and by holding the pressure at all times to the level required for the cut taken, this device increases the cutting capacity of the machine and its mechanical efficiency, and at the same time induces variation in back pressure and consequent irregularity of table movement.

Efficiencies of Otto and Diesel Engines

By F. O. ELLENWOOD, F. C. EVANS, AND C. T. CHWANG

Respectively, Professor of Heat-Power Engineering, Cornell University, Ithaca, N. Y.; former Associate Professor of Heat-Power Engineering, Cornell University, now of Newport, Del.; and former graduate student of Heat-Power Engineering, Cornell University, and now of Washington, D. C.

THIS paper gives primarily the results of calculations for the ideal Otto and Diesel engines in which the working substance is a mixture of real gases. The results are presented in the form of convenient tables and curves that may be readily used by any engineer in the determination of the engine efficiencies of internal-combustion motors operating under the various conditions existing today. The general method of procedure is fully explained and the necessary equations are given.

The paper also considers the factors involved in the establishment of "real-mixture standards" on which to base the performance of Otto and Diesel engines, and compares the results obtained by somewhat different conceptions. The use of higher and lower heating values of the fuel in the various calculations involved is discussed and the tables and curves for the 65 cases considered give the results for both values.

The importance of using engine efficiencies to express performance is stressed, and five illustrative examples indicate that some of the best internal-combustion motors have already been so well designed and built that they give the excellent result of engine efficiencies as high as 76 per cent.

The New Propeller-Type High-Speed Windmill for Electric Generation

By E. N. FALES

Aeronautical Engineer, Keokuk, Iowa

A NEW technology of windmill research adopted from aeronautics has resulted in an improved type of windmill resembling an airplane propeller which, because of its high speed, light weight, low cost, and good efficiency, may compete with internal-combustion-engined farm-lighting plants. Extensive wind-tunnel and other tests used to perfect the new windmill are described, and the theories of design are explained in the first section of this paper. The second section presents a study of the velocity and prevalence of winds at Dayton, and explains how these conclusions can be adopted for other localities using a few basic wind values for those localities. Given the power output required momentarily and on a monthly basis, and the velocity and frequency of the winds, the windmill diameter can be calculated. Coefficients are presented for relating the effects of widely ranging winds with steady wind conditions used in the laboratory for determining fundamental design factors.

Characteristics of Hydraulic Feed and Drive for Cutting Tools

By WALTER FERRIS

Vice-President and Chief Engineer, The Oilgear Co., Milwaukee, Wis.

IN THIS paper the author attempts to show that the application of hydraulic feed and drive for cutting tools has been made possible by the return to the principles of the hydraulic method as it existed before the introduction of the accumulator, and through the introduction of the multiple-plunger pump. The general principles of hydraulic devices used for driving or feeding apparatus for machine tools are presented, particular attention being given to speed control and adaptability to control of inertia forces. The hydraulic drive may be applied either as a straight-line device or as a rotary device. Actually experience during the past five years has developed some peculiarities in the application of hydraulic feeding as compared with geared nuts, and these are described and discussed by the author. These peculiarities affect more the design of the tools than their field of application. In this connection the author describes the regulating devices and the various types of the application of hydraulic drive, in particular, variable-delivery pumps with closed hydraulic circuits vs. constant-delivery pumps with bypass circuits. He considers flexibility to be the most obvious peculiarity of hydraulic feeds, and illustrates by examples its value.

The Steel-Wool Industry

By CROSBY FIELD

Vice-President, Brillo Mfg. Co., Brooklyn, N. Y.

IN THIS paper the author briefly deals with the industry, its art, extent, and recent development. Various machines and processes for making steel wool are described and illustrated, and particulars are given of a fully automatic and continuous machine for manufacturing this abrasive.

Apprentice Training for Draftsman

By C. J. FREUND

Apprentice Supervisor, The Falk Corporation, Milwaukee, Wis.

POINTING out the enormous changes produced in industry through standardization and quantity production, with the resulting increase in specialized production machinery, the author emphasizes the fact that the problem of the draftsman is now to design machinery and machine parts which, while theoretically correct in design, can be easily and economically manufactured in large quantities. To do this successfully, he explains, requires a knowledge of shop practices and cordial coöperation between shop and drafting room. The best method of securing this coöperation, he says, is for the draftsman to spend considerable time actually working in the shop.

He then takes up training of draftsmen through the apprentice system and tells of the importance of a general training that will acquaint the apprentice with the methods and atmosphere of the shop. He outlines the plan of training adopted by the Falk Corporation, both in its general course and the one provided for high-school graduates, giving the usual routine and curriculum and the extent of control by the apprentice department, together with the successful coöperation with the vocational school of the state. He reports a very successful experience by the company for over four years, with seven graduates giving excellent results in the company's employ and other graduates very successful elsewhere.

The Development of Hydraulic Feeds on Multiple Drilling Machines

By R. M. GALLOWAY

The National Automatic Tool Co., Richmond, Ind.

THE author tells first of the three types of hydraulic pumps in general use for feeding machine tools: namely, the gear pump, arranged to pump at pressures up to 250 lb. and capable of delivering a constant volume at a constant pressure; the multiple-piston pump with variable stroke, built to deliver a variable amount of oil at pressures up to 1000 lb.; and a combination of these two arranged to deliver a large volume of oil at 250 lb. pressure from a gear pump and a smaller volume from a variable-delivery piston pump, both pumps being built into the same housing and interlocked as to control.

Following this, the author relates experiences encountered in adapting hydraulic feeds to multiple-spindle drilling machines. A vertical multiple-spindle drilling machine was designed using an Oilgear automatic pump and a $6^1/_8$-in.-cylinder. This machine was capable of a maximum pressure of 24,000 lb. for feeding drills, with a rapid traverse to and from the work of 80 in. per min. The control of the machine is described and illustrated.

The success of this machine led to the development of smaller machines with less expensive pumps. The Heald gear pump experimented with delivered oil at 200 lb. pressure, and in order to get a desired feed pressure of 7500 lb., it was necessary to use two 5-in. cylinders. The machine is illustrated and the control described.

The success attained led to the development of self-contained units which could be built into designs of special drilling machines, as it was found that a single gear pump could be arranged to supply all the feed cylinders. These have been built into machines having from 2 to 7 units. Three sizes of units were built, the smallest

having a 3-in. cylinder with a 6-in. stroke, the second a 4-in. cylinder with a 12-in. stroke, and the third a 6-in. cylinder with a 16-in. stroke. The paper concludes with a statement of some of the lessons learned during the development.

Hydraulics and Modern Machine-Tool Design

BY WALDO J. GUILD

Chief Engineer, Heald Machine Co., Worcester, Mass.

AFTER showing that incompressible fluids have advantages over air for machine-tool drive and operation, the author shows how the pressure and volume of the pumping unit are determined by the energy required of the device in a unit time, and passes on to a study of the control devices for regulating the volume of fluid delivered by the pumping unit, by varying either its speed or its displacement. Applications of hydraulics to several types of machine tools are then described, with brief comments on the valves employed and on air accumulation in the oil lines.

Viscosity of Lubricants Under Pressure

BY MAYO D. HERSEY AND HENRY SHORE

Respectively, former Associate Professor of Properties of Matter, Massachusetts Institute of Technology, Washington, D. C., and Research Engineer, Radio Corporation of America, New York, N. Y.

THE five oils selected for this investigation are believed to be typical of the better-known classes of animal, vegetable, paraffin-base, naphthene-base, and blended oils. The maximum pressure and temperature reached were respectively about 57,000 lb. per sq. in. and 284 deg. fahr. Lard oil solidifies abruptly on passing through a critical pressure which, at 71.6 deg. fahr., is about equal to 22,000 lb. per sq. in. The paraffin-base oil shows a somewhat similar effect. For all of the oils tested except, notably, lard oil it was found that the temperature coefficient of viscosity is considerably increased under moderately high pressures. These and other facts brought out in the paper may have numerous applications in future lubrication research, and have been thought by the Special Research Committee on Lubrication to be of particular interest in the study of oiliness phenomena.

Diesel Locomotives

BY R. HILDEBRAND

Chief Engineer, Diesel Department, Fulton Iron Works Co., St. Louis, Mo.

OBJECTIONS to the steam locomotive are made on grounds of inefficiency, the author stating that 98 to 92 per cent of the heat in the coal is being wasted, while a Diesel locomotive has an efficiency of about 33 per cent. The Diesel locomotive, however, cannot be started under full load, cannot carry any overload without excessive pressures and temperatures, and is so inflexible that an indirect drive or transmission is necessary. The principal objections to the indirect drive are cited by the author, who then makes the proposal of improving the cylinders of the steam locomotive so that they may be used either as steam or Diesel cylinders or as both simultaneously, thus retaining the advantages of both types of engine. An explanation of the working of such an engine is given, and the conditions under which the various combinations of operation are to be used are explained. Typical indicator cards for steam, for Diesel, and for combination operation are given, and the advantages of the system are explained. In closing, the author answers a number of questions and objections which naturally present themselves.

Materials for Aircraft Parts Subjected to High Temperatures

BY J. B. JOHNSON

Chief, Materials Branch, Engineering Division, Air Service, War Department, McCook Field, Dayton, Ohio

IN AIRCRAFT there are only a few parts whose materials are subjected to temperatures above atmospheric. These are confined to engine parts heated by the combustion of the charge. The temperatures attained in aircraft engines are higher than those of automobile engines due to the use of greater mean effective pressures and the development of more horsepower per cylinder. The selection of material for these parts, in order to assure safe and continuous operation, requires a knowledge of the operating temperatures and the properties of the materials at these temperatures. This paper describes the operating conditions and the materials which are now being used. The desirability of developing better materials to meet the requirements of modern design is also considered.

Budgetary Control

BY J. P. JORDAN

Stevenson, Harrison & Jordan, New York, N. Y.

IN THE influence held by a chief executive over the mentalities of his subordinates, whereby he secures from them the greatest possible producing effort, lies the real secret of his success. Many executives hold this influence by sheer personality. Others hold this influence by a combination of personality and the careful selection and provision of various schemes whereby the subordinates themselves are more or less automatically spurred on in their efforts.

It is a well-recognized fact that we are a nation of aggressive people; that we take business chances as a matter of course. The widespread interest in sports—golf, baseball, football, tennis, boxing, polo, etc.—are all evidences of the sporting angles of the average American mind; the apparent evidence of a desire either to indulge in or to become interested in a game.

Budgetary control supplies to every one in any kind of a business institution a species of a game. The setting of quotas of performance and budgets of expense brings out a cool and calculating thought of the future and what it should yield. The daily watching of the current transactions becomes as fully absorbing as the watching of the electric score board of a World's Series game. A par has been set and must be beaten.

The psychological effect of budgetary control is its greatest asset, and in this feature alone it takes its place as perhaps the most valuable of all more or less mechanical management aids.

An Investigation of the Performance of Waste-Packed Armature Bearings

BY G. B. KARELITZ

Research Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

SOME of the observations made while experimenting with full-size armature bearings are recorded in this paper. The importance of taking care in the packing of bearings is brought forth. The advantages of a constant oil lift are pointed out, while the effect of grooving is discussed. Bearing-shell temperatures for varying loads and speeds are given. The data collected may be of interest to designers as well as to engineers in charge of maintenance of railway motors.

Some Operating Data of Large Steam Generating Units

BY HENRY KREISINGER AND T. E. PURCELL

Respectively, Research Engineer, Combustion Engineering Corporation, New York, N. Y., and General Superintendent of Power Stations, Duquesne Light Co., Pittsburgh, Pa.

THIS paper gives the principal operating data of six large steam generating units fired with pulverized coal, and installed in four plants. Two of these units are the remodeled boilers of the Fordson Power Plant of the Ford Motor Co., Fordson, Michigan; the third unit is one of the first five pulverized-coal-fired boilers of the Colfax Plant of the Duquesne Light Co., near Pittsburgh; the fourth unit is one of the two boilers of the Stanwix Plant of the Allegheny County Steam Heating Co., in Pittsburgh; and the fifth and sixth units are the two units of the Gould Street Station of the Consolidated Gas Electric Light and Power Co., of Baltimore. All these plants use the storage system of burning pulverized coal, and the units are fairly representative of the large steam generating units now rapidly coming into use.

The operating data are presented graphically and consist of the hourly output in pounds of steam, throughout the period of operation. Whenever the steam generating unit was shut down, the reason therefore is given. There are also presented charts giving the necessary data for the computation of the efficiency for various ratings such as the temperature of flue gases, the percentage of CO_2 in the flue gases, and the incomplete-combustion losses.

The Ruths Steam Accumulator

By R. A. LANGWORTHY

Vice-President and General Manager, Ruths Accumulator Co., Inc., New York

THIS paper explains how the principle of heat storage in hot water under pressure can be applied in many industries. The author presents the fundamental theory of the steam accumulator which embodies this principle and shows how it may be used to reduce fluctuations of boiler load and reduce the production cost of steam in industries where heat and power demands vary through wide limits. After describing the construction, operation, and control of the accumulator, he gives operating data on three installations: a textile mill, a sugar refinery, and a pulp and paper mill.

A Method of Analyzing the Performance Curves of Centrifugal Pumps

By JOSEPH LICHTENSTEIN

Bethlehem Shipbuilding Corporation, Elizabeth, N. J.

THE discrepancy between the theoretical results of the classical one-dimensional theory used in calculating centrifugal pumps and actual practice makes it necessary to introduce correction factors which can only be deduced from tests. The designer of centrifugal pumps has to his disposition an abundant amount of ordinary performance curves. This paper presents a graphical as well as an analytical method of determining from these test curves all the correction factors necessary to bring in accordance theory and practice. At the same time these correction factors are introduced into the equations of the classical one-dimensional theory, and new equations are thus developed which can be used for calculating new pumps, on the supposition that these correction factors are known.

Back Pressure and Cut-off Adjustment for the Locomotive

By T. C. McBRIDE

Manager, Locomotive Feedwater Heater Dept., Worthington Pump & Machy. Corp., Philadelphia, Pa.

THIS subject is discussed from the operating standpoint only. The author presents data showing the indicated horsepower, the steam consumption, and the dry coal fired as functions of the back pressure. He points out that on each locomotive there is a different back pressure at which maximum power can be obtained at the lowest cost. He advocates a method to determine the best back pressure experimentally and the analysis of back-pressure gages for the guidance of the locomotive engineers.

The Effect of Running In on Journal-Bearing Performance

By S. A. McKEE

Assistant Mechanical Engineer, Bureau of Standards, Washington, D. C.

A FEATURE recognized by the operators of machines containing journal bearings is that a certain amount of "limbering up" or "running in" is necessary before this type of bearing behaves in a normal manner. This paper describes an investigation made at the Bureau of Standards to evaluate this effect of running in upon the performance of babbitted, full-journal bearings.

A specially designed journal-bearing friction machine provided a method of measuring the frictional loss in a journal bearing when operating under different conditions of load on the bearing, speed of the journal, and viscosity of the lubricant. By correlating these factors in a suitable manner a measure of the effect of progressive amounts of running in on bearing performance was obtained.

The results indicate that running in causes a marked reduction in the frictional loss of a bearing under very severe operating conditions.

In the conclusion, the effect of running in upon the factor of safety of a bearing is pointed out, and the possibility of increasing the efficiency of high-speed journal bearings is indicated by a hypothetical example of a steam-turbine bearing.

Principles of Apprenticeship Organization

By BEN S. MOFFATT

Supervisor Apprentice Training, Caterpillar Tractor Company, San Leandro, Calif.

IF AN apprentice-training program is to succeed, it must be organized in accordance with predetermined standards. The first step is a survey to determine training needs and training capacity, followed by an audit of existing training. The author presents the factors in this survey and discusses cost of training, shop supervision, and the auxiliary classroom instruction in technical subjects to be included in the course. Forms of coöperative courses and the selection of teaching personnel are also treated.

Parallel Operation Between Alternating-Current Generators

By J. W. MORTON AND C. JUUL

Respectively, Chief Engineer, American Brown Boveri Electric Corp., Camden, N. J., and Electrical Engineer, Aarhus, Denmark

AFTER deriving a formula for natural frequency of a single generator on a rigid system, the authors present a formula for the natural frequency of two machines in parallel. They discuss the impulses of the Diesel engine and the natural frequencies required to avoid resonance. They work out a case involving several generators, and show where good or poor operation would be expected.

Measurement of Flow of Air and Gas

By SANFORD A. MOSS

Thomson Research Laboratory, General Electric Co., Lynn, Mass.

FLOW of air or other gas is very commonly obtained by use of so-called measuring nozzles, which may be nozzles with well-rounded or streamline approach, venturi meters, or orifices in a thin plate.

Much experience with such apparatus has been accumulated at the Lynn Works of the General Electric Company by the engineers, past and present, of the centrifugal-compressor department and the Thomson Research Laboratory. This has shown that some items in common use are well-founded, while others are without good foundation, and has resulted in the development of some new items. The present paper gives a brief résumé of all of the items of a satisfactory set-up for laboratory flow measurement, based on this experience.

Special attention is given to points of novelty, including a selection of the fundamental constants for air, and a complete set of practical formulas for computation of the flow from test observations, for air and other practically perfect gases. It is of course to be understood that there are ways of handling the various items other than those given in by the author, which may be equally correct. The paper is not an exposition of all flow-measuring methods, but merely gives one good way of handling each item, regardless of the existence of other ways perhaps equally good.

Control of Factory Overhead

By H. G. PERKINS

Assistant Comptroller, Chrysler Corporation, Detroit, Mich.

THE control of factory overhead is almost synonymous with good management. The so-called uncontrollable items of overhead, as well as the controllable items, are amenable to downward adjustment from many different angles.

Tactful discipline of executives, the education of supervisors in cost of materials and service of their own departments, and study or research to determine better and cheaper materials and methods, are essential to expense control.

Expectancy of promotion, personal recognition and appreciation by the higher executives, assignment of added responsibilities, and payment of bonuses to executives, often greatly influence the esprit de corps of an organization.

Uniformity in output is a factor of greatest importance in the standardization of costs, and for this reason a rate of production not in accordance with current demand for the finished product is often advisable so that costs may be maintained at their proper levels.

A properly designed and vigorously administered budget-control scheme is a very powerful means of overhead control, and should cover such points as the attainability of quotas set, a voice in setting quotas by department heads, the provision of cost data for guidance of department heads, the establishment of well-defined standards of operation for various departments to act as checks on estimates and means of forecasting future performance, and the careful comparison of results with quotas to determine possible future economies.

The K.S.G. Process of Low-Temperature Carbonization

By WALTER RUNGE

Vice-President of International Coal Carbonization Co., New York, N. Y.

THIS paper deals with the development of the "K.S.G." low-temperature process of coal carbonization, the principle of operation, and the field of application of the process. The constructional details of the retorts are described, as are also the method of heating, fuel handling, gas and tar recovery, and the types of coals suitable for the process. The yield of products per ton of coal of a given analysis are tabulated, and expected yields based on typical American coals are estimated. The schedule of heat and power requirements shows that 1,630,000 B.t.u. is necessary to carbonize a ton of coal. The horsepower of the steam-driven units amounts to 35 i.hp. per ton, while 68.6 kw. is required for motors.

Passing on to the by-products, the quality of the coke and tar is discussed, and the amount, analysis, and heating value of the gas evolved are given. The paper concludes with a discussion of some economic phases of the process; the market for the by-products, the expected revenue per ton; cost data of the Essen plant transposed to American conditions for a capacity of 600 tons of coal per day, and the projected commercial development.

Heating and Ventilating of Passenger Cars

By EDWARD A. RUSSELL

Engineer of Design, Vapor Car Heating Co., Chicago, Ill.

AFTER setting forth the essential requirements for ideal passenger-car heating, the author shows the need for larger steam hose, valves, and car connections in long trains, and then describes an automatically controlled vapor system of car heating.

The Motor Truck and L. C. L. Freight

By F. J. SCARR

The Scarr Transportation Service, New York, N. Y.

TRANSPORTATION has advanced in economy and efficiency in proportion to the intelligent application of human ingenuity and capital investment. True advance, however, is not in the development of any single phase to usury in whole or in part the function to which any other phase is particularly adapted and better fitted to perform. A proper scheme of transportation demands that each means be employed in the task for which it is best suited.

Succeeding applications of invention and capital in improving the facilities devoted to the carriage of commodities have increased a thousandfold the ton-miles accomplished by each individual employed in freight service and have decreased, proportionately, the cost per ton-mile of freight transportation.

The railroads are economically best suited for the wholesale movement of freight. The controlling factor in their operation is terminal capacity, and terminal costs and delays are the chief obstacles to their greater participation in the short-haul movement of less-than-carload traffic.

Under the present methods and conditions, the highway operator can move most less-than-carload freight for considerable distances cheaper than the railways. He will continue to maintain an economic advantage for the shorter terminal hauls, but a new instrument of freight transportation, the unit freight container, will permit the profitable rail handling of much of the traffic now trucked greater distances. This will necessarily result in the restoration of this traffic to the railways.

The container will use both the highway vehicle and the railroad in the portions of the total movement for which they are best fitted. The rail cost of less than one cent per ton-mile—or about one-seventh of the cost of movement by motor truck—will apply to the road-haul portion, and the terminal cost will be decreased because of the elimination of at least four man-handlings of the freight. The most important collateral benefits are:

1 Faster handling of freight from shipper to consignee
2 Relief of terminal congestion
3 Elimination of theft and damage claims
4 Reduction in packing and crating costs
5 Reduction in rolling stock devoted to L. C. L. service.

The Development of Machine Tools from a User's Viewpoint

By F. C. SPENCER

Assistant Superintendent, Manufacturing Development, Western Electric Co., Hawthorne Station, Chicago, Ill.

THE author bases his paper on the experiences and practices of the Hawthorne Works of the Western Electric Co., whose development organization is charged with the selection of machine tools. This organization has adopted five standards which affect the design of machine tools: namely, minimum floor space; elimination of accident hazards by properly designed guards; reduction of physical effort by convenient operating arrangements; cleanliness; and appearance. The effect of these standards on labor is next brought out and is followed by a review of the motor-drive program which has replaced all but individually motorized machines with motors generally located in the machine base. Examples of the screw-machine and nutting-machine drive are given. There then follows an account with some details of construction of the development of better and safer punch presses, and machines for drilling small holes in thin metal. The paper ends with a discussion of the possibilities of the hydraulic drive and the importance of giving special attention in the design of all new machine tools to the matters of safety, maintenance, and facility of operation.

The Modern Fire Engine

By KARL W. STINSON

Assistant Professor of Automotive Engineering, Ohio State University, Columbus, Ohio

THIS paper opens with a historical outline of the development of the fire engine, and passes to the general requirements of the modern type and a brief description of the typical gasoline engine. The types of pumps are next considered, and the principle features of the piston, rotary, and centrifugal pumps as applied to fire engines are described. The paper ends with a comparison of gasoline and steam fire engines.

Vibration of Bridges

By S. TIMOSHENKO

Research Laboratory, Westinghouse Electric Manufacturing Company, East Pittsburgh, Pa.

IT IS well known that a rolling load produces in a bridge or in a girder a greater deflection, and hence greater stresses, than the same load acting statically. This "impact effect" of live loads on

bridges is of great practical importance. In this paper the following kinds of impact are analyzed:

1 Live-load effect of a smoothly running load
2 Impact effect of balance weights of locomotive driving wheels
3 Impact effect due to irregularities. These irregularities include irregularities in the track and also flat spots on wheels.

It is shown that the live-load effect of a smoothly running load is small and can be always neglected. The impact effect of balance-weights may be of considerable importance, especially under conditions of resonance, and is most severe on bridges of the shortest span which will allow resonance conditions to occur. For the assumptions made in this paper the minimum length of the span to allow such resonance is about 100 ft.

The impact effect due to irregularities of track may attain considerable magnitude in the case of short girders and rail bearers. By removing such discontinuities in the track as rail joints, a considerable decrease in impact stresses produced in bridge parts directly subjected to the dynamical effect of moving wheels can usually be accomplished.

Stresses and Reactions in Expansion Pipe Bends

By A. M. WAHL

Research Laboratory, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

IN THIS paper methods are outlined for the determination of stresses and reactions in pipe bends, in accordance with exact theory which takes into account pipe cross-section distortion. Formulas for various types of bends are given. The computation of maximum transverse and shearing stresses in accordance with the exact theory is facilitated by means of curves which are given. The theoretical results for deflection and distortion of the pipe cross-section are verified by tests made on small pipe bends at the Westinghouse Research Laboratory. Application of the theory to practical cases is illustrated, while the effect of steam pressure on the amount of flattening is shown to be small.

Short-Time Tensile and Expansion Tests on Plain Carbon Steels and Enduro Metal at Elevated Temperatures

By A. E. WHITE and C. L. CLARK

Respectively, Professor of Metal Engineering, Director Department of Engineering Research, University of Michigan, Ann Arbor, Mich., and Department of Engineering Research, University of Michigan, Ann Arbor, Mich.

THIS paper discusses the properties, as determined by short-time tensile and expansion tests, of plain carbon steels and Enduro metal at elevated temperatures. It opens with a section devoted to the need for information in this field. It next mentions the research work in progress in this country and points out the need for greater refinement in methods of testing. The tests at elevated temperatures are then reviewed.

The original work reported covers short-time tensile and expansion tests on 0.13 and 0.37 and 0.38 per cent carbon steels and Enduro metal at elevated temperatures. In the case of the 0.37 and 0.38 steels, comparative tests on bar and tubular stock are given.

The paper ends with a discussion of the relative merits of five classes of steels at elevated temperatures on the basis of proportional-limit findings. The outstanding steels of each group are then compared and recommendations made as to steels best fitted for high-temperature duty.

Symposium on Shop-Equipment Maintenance

Maintenance of Shop Equipment

By J. R. WEAVER

Assistant Superintendent, Equipment Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Plant Maintenance

By GEO. H. ASHMAN

General Electric Co., Schenectady, N. Y.

Maintenance of Machine Equipment at the National Cash Register Company's Plant

By WM. HARTMAN

National Cash Register Company, Dayton, Ohio

Maintenance of Shop Equipment

By C. S. GOTWALS

Time Study Department, Hess-Bright Mfg. Co., Philadelphia, Pa.

Plant Maintenance and Return on Capital Investment

By W. H. CHAPMAN

Manufacturing Equipment Engineer, Hyatt Roller Bearing Co., Harrison, N. J.

THE first four papers composing this symposium describe the organization of the departments in whose charge this feature of the manufacturing problem is placed by four great American industrial concerns. The duties and responsibilities of the personnel of these departments are set forth, their relations with the production and other departments of the shops in question are described, the value of the records of maintenance expense is pointed out and the methods of inspection to determine the need of repairs are explained in detail. The first paper deals with the methods used by the Westinghouse Electric & Manufacturing Company, at East Pittsburgh, Pa., the second with those adopted by the General Electric Company, at Schenectady, N. Y., the third, the organization at the National Cash Register Company's plant at Dayton, Ohio, and the fourth, the manner in which the problem is dealt with by the Hess-Bright Manufacturing Co, at Philadelphia, Pa. The fifth paper of the symposium is more directly related to the fundamental economics of the question of plant maintenance. After defining plant maintenance as he understands it, the author lists twelve items which he later discusses in detail. He attacks the problem from the point of view of accounting practice in the distribution of maintenance expense and its effect upon invested capital, and after laying down some general principles, proceeds to apply the principles to the study of the twelve items previously enumerated, showing how the expense involved in each should be distributed. Leaving the economic aspects of the question, the author next sets up a personnel organization and physical layout to handle the problem of general plant maintenance. This is followed by some observations and warnings about the handling of repair orders. Finally, in a summary, the author returns to the economic phases of his subject and shows by an example how the proper accounting of expense will affect the return on the investment.

Report on Boiler-Feedwater Studies Committee

FIVE Sub-Committees of the Joint Research Committee on Boiler-Feedwater Studies are to present progress reports of their past year's work at the Annual Meeting in December. As a result of the survey carried on by these committees the Main Committee is impressed with the necessity of more accurate information on the treatment of feedwater, the need of fundamental data concerning the chemical phenomena of water treatment, and the desirability for intensive research as a solution for feedwater difficulties confronting the profession at the present time.

The Committee has planned its research program to include immediate investigations on the problems connected with: (1) Corrosion, (2) Embrittlement, (3) Priming and Foaming, and (4) Condensers, Evaporators, and Deaerators. It is the opinion of the Committee that since these problems are nation-wide in scope, the financing should not be borne by any individual group nor confined to any restricted area, as the investment will effect an ample return in the form of reduced maintenance and higher efficiencies in the operation of equipment.

It is proposed to carry the work forward in close coöperation with state and federal bureaus equipped for such work or at universities where engineering problems of a similar nature are in progress. By such procedure there will be required a minimum expenditure for equipment and other necessary facilities.